Hydropower Study

US Army Corps
of Engineers
New England Division

April 1982

Reconnaissance Report

Knightville Dam, Huntington, Massachusetts

HYDROPOWER STUDY

KNIGHTVILLE DAM

HUNTINGTON, MASSACHUSETTS

RECONNAISSANCE REPORT

APRIL 1982

U.S. Army Engineer Division, New England
424 Trapelo Road
Waltham, MA 02254

FOREWORD

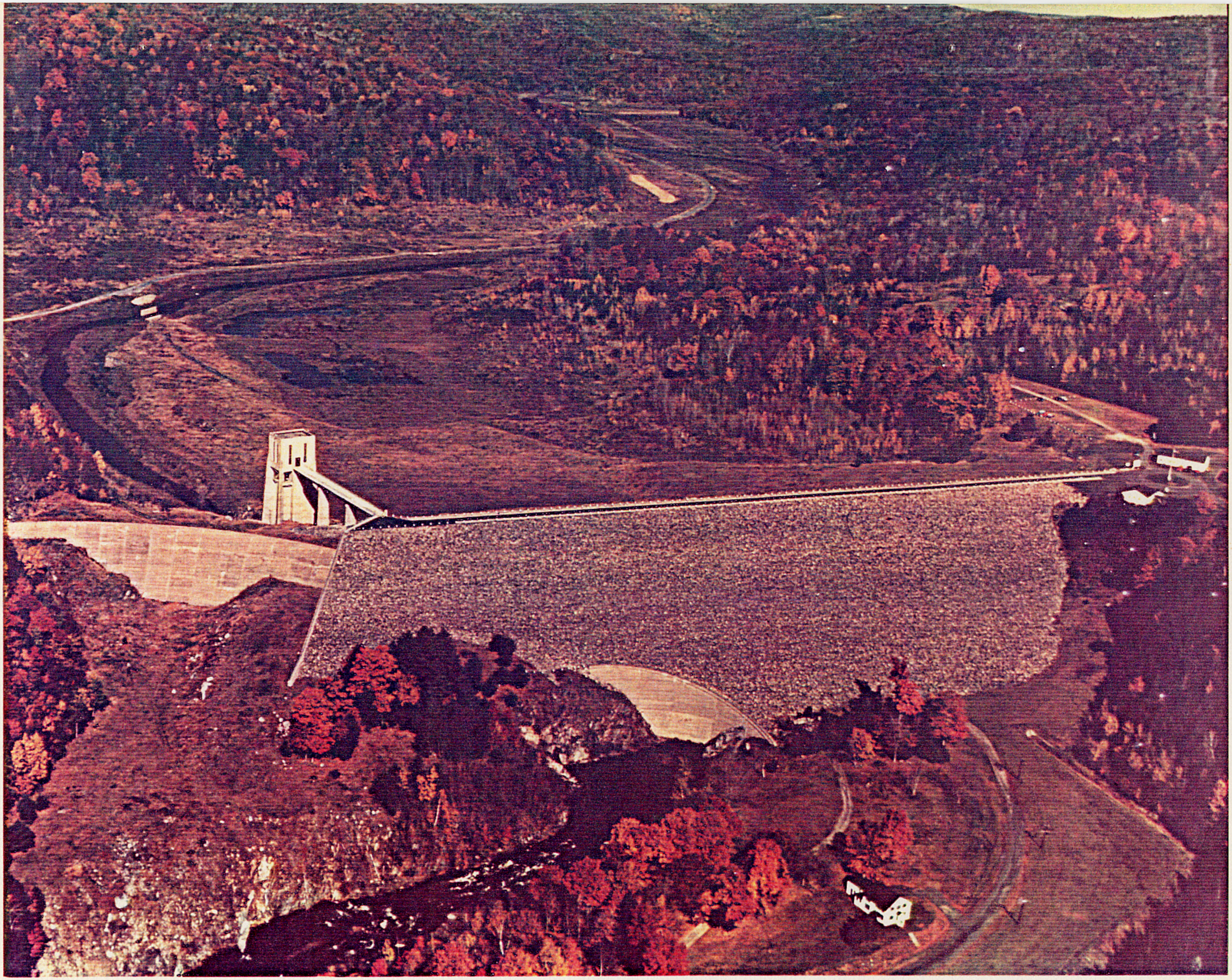
Knightville Dam is an existing Corps of Engineers flood control facility located on the Westfield River in Huntington, Massachusetts. Construction of the project was initiated in 1939 and completed in 1941. As a part of the comprehensive plan for flood protection in the Connecticut River Basin, the project contributes to flood reductions at damage centers on the Westfield and Connecticut Rivers.

This reconnaissance study was undertaken to determine whether the addition of hydropower facilities to the Corps' Knightville Dam is feasible and should be investigated further.

Four plans of hydropower development were investigated as part of this study. The first three plans involved major modifications in order to provide a permanent hydropower pool with a 70-foot hydraulic head. A fourth plan involved a minimum level of development but provided the maximum head considered practical without modifications for increased storage.

The most economical plan, alternative 4, would involve the installation of two 750 KW adjustable blade horizontal turbines, capable of generating 4,718 megawatt-hours annually at a cost of about 94 mills per kilowatt-hour. Implementation of this plan would require the creation of a 35-foot deep, 90-acre permanent pool. The plan is economically feasible on the basis of life cycle cost analysis over a 50-year project life.

As this planning effort continues, detailed studies will be performed to verify these findings, evaluate possible alternatives and further assess environmental, social, recreational and cultural impacts.



KNIGHTVILLE DAM

Environmental Setting

Water Quality

The Little River and the Westfield River above Knightville Dam and downstream to the confluence with the Middle Branch are rated as Class B cold water fisheries by the Massachusetts Division of Water Pollution Control. Technical requirements for these waters include a minimum dissolved oxygen concentration of 6 mg/l, a maximum temperature of 68°F, pH in the range 6.5-8.0 standard units, and fecal coliform bacteria counts not to exceed a log mean of 200 per 100 ml. In addition, there shall be no substances in concentrations that: produce objectionable color, odor, or turbidity; exceed the limits necessary to control eutrophication; or exceed the recommended limits on the most sensitive receiving water use.

There are no significant point source discharges upstream from Knightville Dam; however, some of the upstream communities have significant numbers of residential subsurface disposal systems that are in a failing condition and are essentially discharging untreated sewage to various streams.

The water quality data collected by the NED water quality lab since 1970 shows that the water quality at Knightville Dam is generally good. Recorded violations of Class B cold water fisheries criteria include only rare dissolved oxygen violations and some coliform violation, but frequent pH and temperature violations. Nutrient analyses show high levels of nitrogen but low levels of phosphorus. Heavy metal concentrations are low to undetectable except for occasional, possibly significant levels of zinc and mercury. One additional problem which has been identified is that of occasional heavy silt loads being washed into the river by storms.

Aquatic Ecosystem

The aquatic ecosystem in this area mainly consist of the East Branch of the Westfield River and its six tributaries, including the Little River and Florida Brook. The East Branch is wide, shallow and without cover for most of its 26-mile length. Much of the river length has been dredged so that the bottom consists mainly of bedrock and rubble with occasional sand, gravel and boulders.

Most of the stream length is exposed with only an occasional pool. Water temperatures average 68-69°F during the summer months and may get as high as 87°F. Most pools are generally shallow and become the same temperature as the river water. In tributaries such as Little River, average water temperatures are as low as 65.2°F but may get as high as 75°F.

The East Branch is free flowing lotic habitat except during significant flood storage periods, which have averaged over one per year since 1943. A significant storage of 1 inch of runoff is equivalent to

TABLE OF CONTENTS

TABLES

PLATES

I. INTRODUCTION

Purpose and Authority

This is a reconnaissance report on the feasibility of adding hydroelectric facilities to the existing Corps of Engineers Knightville Dam, located on the Westfield River in west-central Massachusetts. Authority for this study is contained in the resolution of the Committee on Public Works of the United States Senate, adopted 11 May 1962:

> "RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE that the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved 12 June 1902, be, and is hereby, requested to review the reports of the Connecticut River, Massachusetts, New Hampshire, Vermont, and Connecticut, published as House Document Numbered 455, Seventy-Fifth Congress, second session, and other reports, with a view to determining the advisability of modifying the existing project at the present time, with particular reference to developing a comprehensive plan of improvement for the basin in the interest of flood control, navigation, hydroelectric power development, water supply and other purposes, coordinated with related land resources."

Scope of Study

The reconnaissance study has investigated the addition of hydroelectric power development at Knightville Dam. Baseline environmental, recreational, social and cultural conditions in the study area have been identified along with potential problems associated with proposed plans for development.

Study Participants and Coordination

This study was conducted by the New England Division, Corps of Engineers. Information used in the preparation of this report was obtained by New England Division personnel from technical information and construction drawings compiled for the Knightville Dam and from site inspections.

Other Studies

During the initial design of Knightville Dam in 1939, provisions were made for the future development of hydroelectric power by including a penstock transition section in the intake tower structure. This entrance is closed with stoplogs and has not been used to date.

In June 1981, the town of Huntington was issued a preliminary permit, #4046, by the Federal Energy Regulatory Commission (FERC). This permit allows the town to study the feasibility of adding hydroelectric power facilites at the dam. After feasibility studies, the town could apply to the FERC for a license to construct and operate a hydropower facility at the site.

II. PROBLEM IDENTIFICATION

National and Regional Objectives

The primary purpose of the hydropower addition under consideration is to reduce regional (and national) dependence on oil for energy generation. Currently 60 percent of New England's electrical energy is produced at oil-fired generating plants. A hydropower addition to this project would displace oil-generated energy, thereby reducing dependence on oil. Any hydropower plans developed would have to be technically, environmentally, economically and socially acceptable. Any opportunities to enhance the environment that would result from a hydropower addition will be investigated and implemented where possible.

Existing Conditions in the Study Area

Physical Setting

Knightville Dam is one of a system of 16 dams and reservoirs that have been constructed by the Corps as part of a comprehensive plan for flood protection in the Connecticut River basin. Knightville Dam is located in west-central Massachusetts on the main branch of the Westfield River, 4 miles north of the town of Huntington and about 27.5 miles above the confluence of the Westfield River with the Connecticut River in West Springfield, Massachusetts. The project was completed in December 1941. A reservoir plan and vicinity map are shown on Plate 1.

The dam is of the hydraulic earthfill type with a dumped rock shell. It has a top length of 1,200 feet and a maximum height above the streambed of 160 feet. A curved concrete spillway, 400 feet long, is located on rock in a saddle at the west end of the dam. The crest of the spillway is 20 feet below the top of the dam to protect the dam from overtopping during a maximum probable flood. Gated outlet works, founded on bedrock, are located under and at the right end of the dam embankment. The gates, three in number, are normally kept open and the reservoir empty. During times of flood, the gates are closed to store floodwaters in the reservoir. The reservoir has a flood control storage capacity of 49,000 acre-feet, equivalent to 5.6 inches of runoff from the drainage area of 162 square miles. When filled to spillway crest elevation, the reservoir has a surface area of 960 acres and extends about 6 miles upstream in Huntington and Chesterfield. Pertinent data for Knightville Dam is summarized in Table 1.

TABLE 1

PERTINENT DATA - KNIGHTVILLE DAM

Location: Westfield River, Huntington, Massachusetts

Drainage Area: 162 square miles

Storage Use: Flood Control

Reservoir Storage:

	Elevation (ft. msl)	Area (Acres)	Capacity Acre-Feet	Capacity Inches on Drainage Area
Invert Elevation	480	-	-	-
Spillway Crest	610	960	49,000	5.6
Maximum Surcharge	625	1,400	64,000	7.4
Top of Dam	630	-	-	-

Embankment Features:

Type	Hydraulic earthfill
Length (feet)	1,200
Top Width (feet)	30
Top Elevation (ft. NGVD)	630
Height (ft. max.)	160

Spillway:

Location	Right abutment
Type	Chute spillway, ogee weir
Crest Length (feet)	400
Crest Elevation (ft. msl)	610
Max. Discharge Capacity (cfs)	83,000

Outlet Works

Type	One circular tunnel
Tunnel Diameter (feet)	16
Tunnel Length (feet)	605
Service Gate Type	Electrically operated gear-driven slide
Service Gate Size (feet)	Three, 6′0″ wide x 12′0″ high
Channel Capacity (cfs)	4,500
Discharge at Spillway Crest	14,000 cfs

The original design of Knightville Dam included provisions for the future raising of the dam for the generation of electric power. When the lower portion of the intake tower was constructed, an entrance to a proposed penstock was constructed, and a pilot penstock was excavated approximately 50 feet into rock near the base of the intake tower. This entrance was closed with stoplogs and has not been used. It must also be noted that during the war years, 1943 through 1945, a summer pool was maintained in the reservoir at elevation 550± to regulate flows for downstream hydropower generation.

The Westfield River watershed, the fifth largest tributary area to the Connecticut River, covers a large portion of the eastern slopes of the Berkshires in western Massachusetts. The basin is located within the confines of Berkshire, Franklin, Hampden and Hampshire Counties, with a small portion extending into Hartford County, Connecticut, as shown on Plate 2. The watershed has a total drainage area of 517 square miles. Elevations in the watershed vary from 2,505 feet NGVD at Borden Mountain in the headwaters to about 40 feet NGVD at the confluence with the Connecticut River in Agawam and West Springfield, Massachusetts. Topography of the upper portion of the Westfield River basin, above the city of Westfield, is rough and rocky and is drained by many small streams which are conducive to rapid runoff. About 2 miles downstream of Westfield, the watershed is bisected by a row of hills, Provin and East Mountains, which are a section of the Holyoke range.

The Westfield River flows in a deep, preglacial valley in the New England upland section of western Massachusetts. The bedrock hills and ridges are generally blanketed by a thin cover of glacial till, consisting of unsorted materials deposited directly from the glacier and ranging in gradation from clay to boulders. The bottom of most of the main valleys have been deeply filled by deposits of till and outwash. The outwash deposits, which consist of variable, roughly stratified sand, silt and gravel, form narrow floodplains along valley bottoms and terraces on the valley walls. Bedrock outcrops are common through the thin till cover on the upper slopes and tops of the hills. In the valleys, bedrock is exposed only where the rivers have cut through the till and outwash. The bedrock of the region consists of a series of folded Paleozoic crystalline rocks, mostly mica schist, of several formations. The folds trend generally north-south.

The Westfield watershed has a cool semihumid climate typical of the New England region. The average annual temperature is about 45 degrees, with monthly average varying from about 69 degrees in July to about 21 degrees in January. Extremes in temperature range from summertime highs in the nineties to wintertime lows in the minus twenties. The mean annual precipitation in the basin is 46 inches occurring quite uniformly throughout the year, generally as periodic storm fronts of 1 to 2 days duration. Average, maximum and minimum monthly precipitation, as recorded at Knightville Dam, are listed in Table 2. Much of the winter precipitation occurs as snow with an average annual snowfall of about 56 inches. The snowpack usually reaches a maximum in early March with an average maximum water equivalent of about 4.0 inches.

The average annual streamflow in the Westfield basin is about 55 percent of the mean annual precipitation, or 25.7 inches of runoff, equivalent to an average runoff rate of about 2 cubic feet per second (cfs) per square mile of watershed area. Based on 61 years of streamflow records on the Westfield River at Westfield, the maximum annual runoff was 44.1 inches in 1928 and the minimum annual runoff was 11.1 inches in 1965. Though precipitation is quite uniformly distributed throughout the year, the melting of the winter snow cover results in about 50 percent of the annual runoff during the months of March, April and May. Flows are usually lowest during the months of July, August and September.

USGS gage 01179500 is located on the Westfield River just downstream of Knightville Dam. Because the project is operated principally for flood control purposes, the monthly flows recorded at the downstream gaging station are representative of the natural monthly streamflows at the project site.

TABLE 2
MONTHLY PRECIPITATION IN INCHES
KNIGHTVILLE DAM, MASSACHUSETTS
(Period of Record - 1948 - 1975)

Month	Mean	Maximum	Minimum
January	3.08	6.40	0.75
February	3.18	5.11	1.24
March	3.82	10.18	1.28
April	3.68	5.97	0.82
May	3.54	6.73	0.95
June	3.64	9.12	0.57
July	3.39	7.71	1.12
August	3.69	15.27	1.06
September	3.59	8.06	1.38
October	3.46	16.95	0.42
November	4.36	8.11	0.81
December	4.23	9.38	0.65
Annual	43.61	62.36	32.15

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8630 acre-feet of storage. The configuration and size of the East River make this area prone to frequent flash flooding. The total storage (49,400 acre-feet) was utilized in January 1949 and nearly again in October 1955 (47,200 acre-feet). Once maximum storage is attained, water levels return to normal after about a week. During winter, from December through March, a 20 ft. pool is maintained behind the dam to prevent freezing of the sluice gates. Depending on the depth and degree of storage, the shore may accumulate silt and debris following drawdown. Erosion has recently occurred along the east bank but vegetation quickly reestablished itself.

The Westfield River was once a migratory route for Atlantic salmon. Since the industrial age, degradation of water quality near the mouth of the downstream Connecticut River and the installation of 13 dams along the three branches have precluded annual spawning runs. Above the confluence with the Connecticut River, the Westfield River remains a good fishery for trout. The Massachusetts Divsion of Fisheries and Wildlife (MDFW) stocks the Knightville area with about 3,000 trout each spring. Stock species include the native eastern brook trout (Salvelinus fontinalis), the introduced western species rainbow trout (Salmo gairdneri), and the introduced Eurpoean species brown trout (Salmo trutta). Although natural reproduction in the tributaries does occur, most harvested trout have been stocked. The fishing pressure along the stocked area is generally heavy, with about 13.5 miles of stream under lease as designated public fishing areas. The fishery is basically a "put and take" operation. As the water temperature increases during summer months, coldwater species move in to the cooler tributary waters.

Typical warm water species in the East Branch include white sucker (Catostomus commersoni), brown bullhead (Ictalurus nebulosis), yellow perch (Perca flavescens), pumpkinseed sunfish (Lepomis gibbosus), chain pickerel (Esox niger), smallmouth bass (Micropterus dolomieui), sculpins (Cottidae), killifish (Cyprindontidae) and a variety of minnows (Cyprinidae).

Terrestrial Ecosystem

Habitat

Of the 2,430 acres of land acquired for the Knightville project, approximately 2,119 acres are forested, 282 acres are open field and/or shrubby herbaceous bottomland, and the remainder are river area, flood control structures, roads and parking lots. Approximately 450 acres of forest and 280 acres of open land occur below the spillway elevation of 610 feet NGVD.

The forest consists mainly of northern hardwood species such as American Beech (Fagus grandifolia), yellow birch (Betula allegheniesis), and sugar maple (Acer saccharum). Common associated species include the hardwoods: black cherry (Prunus canadensis), white ash (Fraxinus americana), red oak (Quercus ruba), paper birch (Betula apayrifera), American elm (Ulmus americana), and the softwoods: Eastern hemlock (Tsuga canadensis), and white pine (Pinus strobus). Open fields contain such pioneering species as quaking apsen (Populus tremoloides), pin cherry (Prunus pensylvanica), grey birch (Betula populifolia) and several shrub species. Most of the forest cover is mature to overmature second growth hardwood-softwood mixture that was once largely cleared for farming and timber harvesting. The MDFW have planted cover, grain crops and shrubs on the bottomland of both the East and Branch and Little River in conjunction with their pheasant management program.

During construction, the lower reservoir area was cleared of trees to 540 feet NGVD. Frequent flooding kept regeneration of this area to a minimum, and only pioneer species such as aspen and birch have become established near the edge of the treeline.

Ice formation during spring floods have scoured tree line vegetation and soils. Some regeneration on eroded soil and of scraped branches occurs in the following months. Shrub wetlands occur at the reservoir bottom just north of the dam and about 3.4 miles upstream of the dam. The latter is the result of beaver activity. A wooded wetland exists at the confluence of the Little River and East Branch.

Appendix B of the Knightville Dam Master Plan is a proposed forest management plan. This plan outlines various silviculture techniques that would be used to improve forest productivity, reduce areas of erosion, improve protection from disease, and enhance wildlife habitat and public use. Staggered management of selected areas is best suited for this multipurpose plan using techniques such as thinning, pruning, and planting.

Wildlife Resources

The MDFW presently stocks pheasants on 296 acres of Knightville property under a license from the Corps of Engineers. Stocking of 1,000 birds usually occurs in early October, just before hunting season. The management efforts are basically a "put and take" operation.

The above described forest, shrubland and fields provide habitat for a variety of natural game and non-game wildlife species. Big-game species at the project are white-tailed deer (Odocoileus virginianus), and an occasional black beer (Ursus americanus). Upland game species include red squirrels (Tamisascirurus hudsonicus), gray squirrel (Sciurus carolinensis), cottontail rabbit (Sylvilagus transitionalis), varying hare (Lepus americanus), ruffed grouse (Bonasa umbellus), and the American woodcock (Philohela minor). Waterfowl utilization of the project wetland is relatively low but small nesting populations of wood ducks (Aix sponsa), and hooded merganzers (Lophodytes cucullatus) have been observed in the past. During migration black ducks (Anas rubripes), blue-winged teal (anas discors), green-winged teal (Anas carolinesis), and American merganzers (mergus merganzer) use the Westfield River for feeding and resting.

Red fox (Vulpes fulva), gray fox (Urocyon cinereoargenteus), bobcat (Lynx ufus), shorttail weasels (Mustela erminea), opposum (Didelphis marsupialis), and striped skunks (Mephitis mephitis) inhabit the reservoir or include it in their range. Other mammals generally associated with stream environment are racoon (Procyon lotor), mink (Mustela vison), river otter (Lutra canadensis), and muskrat (Ondatra zibethica). A variety of avifauna, reptiles, amphibians and invertebrates also inhabit the area.

Rare, Threatened, Endangered Species

Currently, there are no federally listed threatened or endangered species residing in the project area (U.S. Fish and Wildlife Service, personal communication). According to the Commonwealth of Massachusetts, to date there are no State listed rare species of fauna or flora in the area; however, this is an ongoing process and is continually being updated.

The Massachusetts State ornithologist[1] indicated that the area may serve as habitat for the great blue Heron (Ardea Herodias), the Cooper's hawk (Accipiter cooperii), and the sharp-skinned hawk (Accipiter sciatus). Also, the lake chub (Coaesius slumbeus), which only occurs in the Westfield River Basin, is currently designated as a species of "Special Consideration." There are a number of mammals, reptiles and amphibians which are also given this designation.

Recreational, Cultural, Social and Economic Setting

Recreation Resources

Knightville Dam is presently operated as a dry-bed reservoir solely for flood control purposes. Recreational use in the project area consists of picnicking downstream of the dam, group camping in the upper end of the reservoir in an area rarely subjected to inundation, a small amount of swimming at the group campground, canoeing (primarily downstream of the dam for which water is often held back by the Corps for controlled releases), sightseeing at the dam, fishing, hunting and miscellaneous activities including trailbike riding, snowmobiling and hiking. Hunting and fishing are the only recreational activities that would be significantly affected by the proposed hydropower plans, as a result of the establishment of a lake behind the dam. About half of the fishing and hunting activity takes place in the vicinity of the dam and the rest in the reservoir area. The Massachusetts Division of Fisheries and Wildlife stocks approximately 3,000 trout and 1,000 pheasant in the project area.

[1]Letter dated, August 7, 1980, Massachusetts Division of Fisheries and Wildlife

Most of the hunting is for pheasant in the shrub bottomland consisting of about 296 acres and extending upstream from the dam for about two miles.

The following table indicates the average annual visitation and percentage of total use of the major recreational activities at Knightville over the past four years:

Sightseeing	Fishing	Hunting	Canoeing	Picnicking	Camping
31,000	3,800	2,500	2,300	2,000	1,900
71%	9%	6%	5%	5%	4%

Historic and Archaeological Resources

Prehistoric occupation of the East Branch of the Westfield River in the vicinity of Knightvile Dam probably consisted chiefly of small campsites which were seasonally occupied. These could have been located to obtain migratory fish or wildlife species, or seasonally available plant resources. The valley would have provided a route of travel between the Connecticut River and Housatonic River drainages.

Extant prehistoric sites would most likely be located on terraces above the floodplain. The only recorded prehistoric site within the present project limits is in the vicinity of Indian Hollow, an area fitting this description. Unrecorded sites may exist at similar locations within the project, or in rock shelters on the slopes above the valley.

The Knightville Dam is located in an area which was first a portion of Murrayfield, incorporated in 1765. In 1775, the town was divided into the present towns of Chester and Norwich (reincorporated as Huntington in 1855).

Settlement followed a typical upland pattern. The first town center was atop Norwich Hill, 2 kilometers east of Knightville Dam. After an initial period of population growth, a gradual decline began in the early 19th century as a result of emigration of farmers to New York and the Old Northwest. During the second quarter of the century industry began to offset this decline, and the present Huntington Center emerged as the town's major population-mercantile-industrial center. It was not until after 1875 that manufacturing population approached that of agricultural personnel. The town today is a focus of small manufacturers and some farming but also functions as a suburb of the city of Westfield.

Industry in the town began with the usual pattern of agrarian-oriented mills (sawmills, gristmills, etc). Huntington center boasted a succession of small textile mills, which operated from the 1840's to 1952, and a fairly large paper mill, built in 1853 and burned in 1942.

The village of Knightville became a secondary population center during the mid-19th century. In 1855, a shop owned by E & T Ring and employing 15 hands produced toy wagons and sleds. This shop may have been in operation in 1873, producing baskets. A sawmill and other small mills may also have existed at some time.

Recorded historic period sites remaining within government property consist of four bridge sites, two cemetery sites, three factory sites, a charcoal kiln site, a school site, and 19 house sites with associated outbuilding remains. Though superstructures of all buildings were removed during dam construction, most foundations are fairly intact though heavily overgrown with brush. All internments in the cemeteries were removed to other locations prior to dam completion.

Nineteen of the recorded historic period sites within government property are inundated at least once per year by flood control operations. Six others have been inundated less frequently, and four are either above present spillway elevations or downstream from the dam. As most sites are heavily vegetated, there appears to be little erosion resulting from these temporary inundations.

Socioeconomic Resources

The Westfield River Basin encompasses, either wholly or partially, approximately 30 communities in western Massachusetts. Communities in the northern portion of the watershed are primarily rural and sparsely populated. More concentrated population centers, including the cities of Westfield, West Springfield, Holyoke and the town of Agawam, lie in the southern portion of the watershed.

Early development within the basin occurred along the rivers and streams on the eastern slopes of the Berkshires during the mid-1700's. The establishment of grist, saw and paper mills and tanneries characterized early industry. However, due to the rugged terrain throughout the region, expansion of industry was limited to the southeastern portion of the watershed, with the northern communities concentrating on agricultural activities.

Holyoke, with a population of 44,678 in 1980, is the most populated community in the watershed, followed by Westfield with 36,465, West Springfield with 27,042, and Agawam with 26,271. All of the other communities with the exception of Tolland and Suffield, Connecticut, and Southampton, Massachusetts, have populations under 2,000. The towns of Huntington and Chesterfield both showed growth between 1970 and 1980. Huntington's population grew 13.2 percent to 1,804, and Chesterfield's population grew 42.0 percent to 1,000. Overall, the basin communities have continued to experience population increases with Holyoke the only city to show significant losses.

Many residents living in the northern portion of the watershed are still engaged in agricultural activities. Other residents commute to jobs in the larger population centers in the Pittsfield and Springfield-

Chicopee-Holyoke (SCH) Standard Metropolitan Statistical Area (SMSA). Manufacturing is the largest employment sector in the southern portion of the watershed, although it has experienced a decline in total number employed. Sectors showing increases in employment include the services, finance, insurance and real estate sectors.

Reservoir Regulation

The principal objective of Knightville Dam is flood control. Both Knightville Dam and Littleville Lake which is located about two miles to the southwest, are regulated to reduce flood stages at Westfield, West Springfield, and other communities on the Westfield River and, in conjunction with 14 other projects in the reservoir system, to reduce downstream flood stages along the Connecticut River. In addition, water-based recreational activities are utilized at both projects.

Knightville Dam was authorized as a dry-bed reservoir and has a normal gate setting during the nonfreezing season of 3'-0'-3'. During the winter, a pool is maintained at about a 20-foot stage to prevent freezing of the flood control gates.

Regulation of flows from Knightville Dam are initiated for heavy rainfall over the Westfield River watershed and also from specific river stages at key Westfield and Connecticut River index stations. A minimum release of about 20 cfs is maintained during periods of flood control regulation in order to sustain fish life immediately downstream from the dam.

Following the downstream recession of a flood on the Connecticut River, stored floodwaters are released as rapidly as possible, consistent with amounts of reservoir storage utilized, downstream flows, channel capacities, weather forecasts and travel times. The maximum nondamaging channel capacity downstream of the dam is about 4,500 cfs. Releases of this magnitude are not usually made unless considerable flood control storage is utilized.

During the release phase, the levels at downstream points should not exceed flood stage; however, during an unusual flood it is possible that flood stages may continue to be exceeded due to runoff from uncontrolled downstream tributaries, and it may be necessary to begin releases once the stage has crested.

Ordinarily during a major flood, the gates would not be opened to avoid spillway discharge. Surcharge storage above the spillway crest would be utilized if downstream channel capacities continue to be exceeded by runoff from uncontrolled areas. However, if the stage in the reservoir continued to rise above the crest with the possibility of endangering the structural integrity of the dam, releases might be made through the gates. Under such circumstances State and local police would be advised of the threat.

It is conceivable that an extraordinary situation could arise, such as: drowning, dam or bridge failure, highway or railroad washout, ice jam or debris deposit. Since the purpose of the reservoir is to save lives and prevent or reduce damage, regulation during such unusual conditions not follow previously described rules, but would be governed by the urgency of the circumstances. During such situations the project would be shut down immediately.

It is the policy of the Corps of Engineers to cooperate with downstream water users and other interested parties or agencies. The Project Manager may be requested by downstream users to deviate from normal regulation for short periods. Whenever such a request is received, the manager ascertains the validity of the request and obtains assurances for other downstream water users that they are agreeable to the proposed operation.

Future Conditions Without the Project

No significant changes in the physical, environmental, cultural, social and economic conditions are anticipated in the study area. No significant changes in reservoir regulation are envisioned.

Problems, Needs and Opportunities

New England depends heavily on oil for its electricity. About 60 percent of the region's electricity is produced at oil-fired generating stations. Given the instability of oil supplies and the fluctuating prices associated with them, the need for the development of renewable resource projects is apparent. The addition of hydropower at Knightville Dam would reduce the region's dependence on oil for the production of electricity.

III. FORMULATION OF PLANS

Management Measures

There are a number of management measures which may be employed to reduce New England's dependence on oil for the production of electrical energy. Structural measures include conversion of oil-fired facilities to coal, building additional coal; nuclear facilities; construction of hydroelectric and tidal power projects, and development of alternative energy sources such as wind, passive solar, coal liquification or gasification photovoltaics, wave action, geothermal, wood, and other biomass; also purchases of imported power. Nonstructural measures would consist mainly of conservation and load management. The advantages and disadvantages of the various energy alternatives and management techniques for reducing oil dependence are outlined below.

The conversion of oil-fired facilities to coal would reduce the amount of oil presently needed for electric energy production. The concept is technically sound and would be cost effective at many facilities. The conversion, however, is not without problems. Key factors that must be considered are the availability of water or rail transportation facilities and protection of ambient environmental quality.

The construction of new coal and nuclear facilities also directly reduces oil use. New coal facilities have problems similar to converted facilities and the current social-political climate in New England makes development of nuclear projects difficult.

Hydroelectric facilities, including run-of-river, pumped storage, conventional and tidal power, are powered by water - a renewable resource. While these projects do not degrade air quality or create dangerous waste materials, they permanently alter existing physical conditions at the project site, sometimes displacing inhabitants and adversely affecting resident wildlife. Energy generated by single pool tidal power projects and run-of-river hydropower projects is dependent on natural phenomena, such as tides and runoff. Man cannot control when fuel will be available, but can make predictions with reasonable accuarcy.

Wind power is one of the oldest forms of energy. Wind power is clean and many sites are available; but energy from such a project is intermittent.

Active and passive solar energy offer some potential. Active solar is basically an at-site technology which is useful for space and hot water heating. Passive solar design generally decreases the energy needs of a structure but does not generate energy.

Other energy alternatives are liquified coal, photovoltaics, nuclear fusion and biomass. These, perhaps, will be the predominant energy sources of the 2000's. Once fully developed, these technologies could lead to energy independence for the Nation.

Purchases of imported power would reduce our direct dependence on oil but do little to enhance our energy independence.

Conservation is perhaps the best short-term answer to oil use reduction. Lower thermostat settings, insulation and other conservation methods directly reduce oil use and have limited impacts on changes of life style.

Load management is primarily aimed at rearranging the timing of electric demand. This involves the changing of people's habits. Once established, load management would allow more use of base load and intermediate power sources (lower cost coal, nuclear and hydroelectric) and require less peaking power (expensive pumped storage and oil dependent combustion turbines). Of course, load management assumes that nuclear and coal energy sources will continue to be developed and ultimately displace existing oil-generating facilities.

Plan Formulation Rationale

The purpose of this investigation was to determine the feasibility of adding hydropower facilities to the Knightville Dam. A cursory analysis was made of four different plans for hydropower development. Alternatives 1, 2 and 3 involved major modifications to existing project features in order to provide a permanent hydropower pool with a 70-foot hydraulic head. Alternative 4 involved a minimum level of development but the maximum head considered practical without modifications for increased storage. For this report, assumptions have been made assuming that the Corps would plan, develop, construct and operate the hydropower addition.

Description of Plans

Plan 1 would involve raising Knightville Dam 9 feet, thus providing 9,760 acre-feet of permanent pool storage for hydropower and creating 70 feet of hydraulic head. The existing 16-foot diameter outlet tunnel would be steel-lined for use as a penstock. Twin hydropower units would be installed downstream with a combined hydraulic capacity of 640 cfs and generating capacity of 3 MW. Three 10-foot and one 2-foot diameter butterfly valves would also be provided at the downstream end of the penstock for both low flow and flood regulation. The potential average annual generation with such a plan of development was computed to be 9,437 megawatt-hours.

Plan 2 is identical to Plan 1 except that instead of raising the dam, the existing spillway crest would be lowered 2 feet and a 400-foot long, 10-foot high bascule gate would be installed to permit 9,758 acre-feet of added regulated storage, thus providing for a 70-foot deep permanent hydropower pool. This plan would provide the same 9,437 megawatt hours of average annual generation.

Plan 3 is identical to Plan 2 except that instead of steel lining the existing 16-foot diameter outlet tunnel for use as a penstock, a separate 12-foot diameter tunnel, approximately 800 feet in length, would be excavated for use as a penstock. This plan would provide the same 9,437 megawatt-hours of average annual generation.

Plan 4 is a hydropower develoment plan to provide a hydraulic head of 35 feet. At pool elevation 515 feet NGVD, a head of 35 feet represents 1,340 acre-feet of lost flood control storage equivalent to .15 inches of runoff from the contributing watershed. This was considered the maximum encroachment permissible without providing mitigating flood control storage. These values were used for preliminary planning purposes only, and future studies would be required to determine the effect this loss of flood control storage would have on downstream flood damage reduction. This plan included steel lining the 16-foot diameter outlet tunnel and providing twin hydropower units downstream with a combined hydraulic capacity of 640 cfs and generating capacity of 1.5 MW. Three 10-foot diameter butterfly valves were also included for streamflow regulation. This plan would provide a computed average annual generation of 4,718 megawatt hours.

Sketches of these plans are contained on Plates 7 through 10.

TABLE 3
PERTINENT DATA ON ALTERNATIVE
PLANS OF HYDROPOWER DEVELOPMENT
AT KNIGHTVILLE

Plans		Capacity (cfs)	Capacity (mw)	Head (ft)	Annual Energy (Megawatt-hours)
1	Raise Dam 9 feet Steel line outlet	640	3.0	70	9,437
2	Install Bascule Gate	640	3.0	70	9,437
3	Independent Penstock Tunnel	640	3.0	70	9,437
4	Minimum Head	640	1.5	35	4,718

TABLE 4

STORAGE-ELEVATION DATA
KNIGHTVILLE DAM
(Drainage Area = 162 Square Miles)

	Elevation (ft, NGVD)	Stage (ft)	Pool Area (acres)	Storage (ac-ft)	Runoff (inches)
Invert	480	0	0	0	0
Proposed Pool 35′ Head	515	35	90	1,340	0.15
Proposed Pool 70′ Head	550	70	370	9,760	1.13
Spillway Crest	610	130	960	49,000	5.6
Maximum Surcharge	625	145	1,400	64,000	7.4
Top of Dam	630	150	-	-	-

Power Estimates

The hydropower potential of a volume of water is the product of its weight and the vertical distance it can be lowered. Water power is the physical effect of the weight of falling water. The function of a water power facility is to transform this gravitational potential energy into mechanical energy, by turning a turbine, for utilization in creating electrical energy via a generator. The potential rate of power generation, normally measured in kilowatts, is determined by the formula:

$$P = \frac{EHQ}{11.8}$$

where:

P = Power or capacity in kilowatts
E = Combined turbine and generator efficiencies
Q = Rate of discharge in cubic feet per second
H = Net hydraulic head in feet.

With today′s highly efficient turbines and generators, an average combined efficiency of 80 percent can be reasonably assumed for a typical range of operating head and discharge conditions. The potential amount of power generation over a period of time, "energy," is normally measured in kilowatt-hours and is equal to the average capacity times the duration of generation.

The potential amount of water power of any stream, river or lake is a function of: (1) the average annual streamflow and (2) the average annual hydraulic head. Both the rate of discharge and the head are quantities which may fluctuate; therefore, it is the magnitude of these two quantities and their variability that determine the potential energy of a site and its dependability.

At Knightville Dam there is presently no permanent pool providing a hydraulic head. Therefore, there is presently no hydropower potential at the site without the creation of a permanent pool. With an average annual flow of 326 cfs at the site, the theoretical potential maximum average annual energy from the site would be 194 megawatt hours times the average feet of hydraulic head provided.

As previously stated, the average annual flow at the site is about 326 cfs. Table 5 shows average monthly flow data over the period of record at the USGS gaging station located just downstream of Knightville Dam.

TABLE 5
AVERAGE MONTHLY FLOWS (1910 - 1981)
WESTFIELD RIVER AT KNIGHTVILLE, MASSACHUSETTS
(Drainage Area = 162 Square Miles)

Month	Average Flow		Percent of Annual	Maximum Monthly		Minimum Monthly	
	CFS	Inches	Runoff	CFS	Inches	CFS	Inches
January	300.0	2.1	7.7	1,305	9.3	45	0.3
February	273.0	1.8	6.6	854	5.5	54	0.4
March	618.0	4.4	16.1	2,050	14.6	147	1.0
April	937.0	6.4	23.4	1,757	12.5	203	1.4
May	436.0	3.1	11.4	1,088	7.7	110	0.8
June	230.0	1.6	5.9	272	1.9	41	0.3
July	123.0	0.9	3.3	479	3.4	21	0.2
August	104.0	0.8	2.6	745	5.3	16	0.1
September	125.0	0.9	3.3	986	7.0	16	0.1
October	170.0	1.2	4.4	1,394	9.9	18	0.1
November	297.0	2.0	7.3	1,155	8.2	39	0.3
December	306.0	2.2	8.1	1,033	7.3	62	0.4
Annual	326.0	27.3		537	45.7	137	11.7

A flow duration curve is a graphical representation of discharge rate versus percent of time. As such, the flow duration curve is a measure of magnitude and variability of flow. It does not account for the sequence or time at which flows of various magnitudes occur. Since the area under the curve represents the average amount of water available, it is possible to estimate average annual generation within the operating range of flows for the selected unit. A flow duration curve for the gage at Knightville Dam is shown as Plate 5.

There are two basic classes of hydraulic turbines - impulse turbines and reaction turbines. The fundamental difference is that impulse turbines are driven by the kinetic energy of a high velocity jet, whereas reaction turbines are driven by the combined pressure and velocity of the water.

The impulse design has cost-effective operating characteristics for high heads (800 feet and higher) and is not suitable for the Knightville project. Reaction turbines have two basic types of runners - Francis runners and propeller runners. With the Francis runner, flows enter the runner radially and exit axially, whereas, with the propeller runner, the flows enter and exit axially. The Francis type runner is more applicable to higher head installations and is usually cost-effective at heads of 100 feet or more. The propeller runner is more applicable to the lower head-higher discharge installations. It can operate at heads up to 100 feet but is usually most cost effective at heads of 60 feet or less. A vertical propeller runner with adjustable blades is known as the "Kaplan" runner. Both turbine types are normally equipped with wicket gates to permit placing the unit on line at synchronous speed, to regulate load and speed, and to shut down the unit. Both the Francis and propeller turbines can be of a horizontal or vertical design - the axis of the runner being in the vertical or horizontal plane. There are also propeller turbines of slant design. Both the Francis and Kaplan turbines are equipped with wicket gates and can operate quite efficiently under varying discharge from about 40 to 105 percent of design capacity. The Francis unit can operate under varying head for about 60 to 125 percent of design head, whereas the Kaplan can operate satisfactorily in a range of 60 to 140 percent of design head.

For purposes of this reconnaissance study, the horizontal adjustable blade, tube-type turbine was assumed most appropriate for those alternative plans at Knightville involving a 35-foot hydraulic head. For plans at Knightville involving a 70-foot hydraulic head, horizontal Francis turbines were considered appropriate; however, it is believed that in any final design studies, the horizontal adjustable blade, tube-type turbine may be found to be equally or somewhat more cost effective.

Considering the size of installation, the variability of flow and the "run-of-river" type operation that would take place at Knightville, twin turbine units were assumed for all Knightville alternatives in order to provide the needed operating flexibility.

Characteristics of the various turbine types and sizes were obtained from manufacturer literature and from the July 1979 Corps of Engineers report entitled: "Feasibility Studies for Small Scale Hydropower Additions - A Guide Manual."

The selection of turbine unit size for each alternative was based on the head and flow characteristics at the site, plus in some cases, the hydraulic capacity of existing facilities at the project. The selected capacities were those adequate to harness a major portion of the hydropower potential of the site and result in reasonable average annual plant factors. Further optimization of selected installed capacities may result with more detailed design studies. However, use of available "package" type turbine and generator units should provide economies over custom designs.

Generators are either synchronous or induction types. The synchronous unit is equipped for self excitation and synchronization before going onto the grid; whereas the induction generator relies on power from the grid for excitation. Induction generators are somewhat cheaper in cost and more applicable to small installations; however, utility companies are reluctant to have numerous small units in the system capable of draining power from the grid for excitation. Therefore, for this reconnaissance study, synchronous generators were assumed for all plans. Generators would have rated capacities equal to or greater than the rated turbine capacity and also be capable of operating continuously at a 15 percent overload.

Comparative data for the alternatives is shown in Table 6.

TABLE 6

KNIGHTVILLE DAM HYDROPOWER DEVELOPMENT
PERTINENT DATA

	Alt. 1-3	Alt. 4
Number of Units	2	2
Throat Diameter (ft.)	3.5	4.1
Hydraulic Head (ft.)	70	35
Hydraulic Capacity (cfs)	640	640
Generator Type	Synchronous	Synchronous
Generator Capacity	1,500 kw each 3,000 kw total	750 kw each 1,500 kw total
Potential Annual Generation	9,437,000 kwh	4,718,500 kwh
Plant Factor	0.35	0.35
Turbine/Generator Efficiency	80%	80%
Types of Turbine	Horizontal Francis	Standard Tube

Project Operation

Plans 1, 2 and 3: Each of these plans would consist of two 1.5-megawatt horizontal Francis turbines, each capable of discharging 320 cfs under a head of 70 feet. The units would be equipped with synchronous generators with not less than 1,500 kilowatt capacity each. Therefore, the total hydraulic capacity would be 640 cfs at a head of 70 feet, capable of generating 3,000 kilowatts of power.

Knightville is presently a dry bed reservoir with outflow equal to inflow except during flood periods. With each plan, the operation would still be basically outflow equal to inflow except the outflow would pass through the turbines for power, within the limits of the capacity of the units. With this hydropower installation, generating flows would range from a low of about 130 cfs to a high of 640 cfs. The project would be operated as a run-of-river project and when the inflow was less than 130 cfs, generation would cease and outlet discharge would be maintained approximately equal to inflow. There would be no generation about 40 percent of the time, occurring mostly during the period July through October. Such a project would be viewed mainly as a "fuel saver" with no dependable capacity. Outflows varying from 130 to 640 cfs would be used for generation, and the project would be operating at design capacity continuously about 15 percent of the time generally occurring in March and April.

Plan 4: This alternative installation would consist of twin 1250-mm, variable blade, horizontal tube type turbines each capable of discharging 320 cfs under a head of 35 feet. The units would be equipped with synchronous generators with not less than 750 kilowatt capacity each. The total hydraulic capacity would be 640 cfs at a head of 35 feet, generating a maximum of 1,500 kilowatts of power. The operation of this plan would be basically the same as for the previous alternatives, except the normal power pool would be elevation 515 NGVD rather than 550 NGVD. With a hydraulic head of 35 feet, the head pool will have a surface area of about 90 acres.

Cost Estimates

Cost estimates contained in this section have been prepared by using standardized cost curves taken from the Corps publication entitled, "Feasibility Studies for Small Scale Hydropower Additions" and by preparing site-specific estimates using standard engineering practices. Estimates of first cost for the alternatives are presented in Table 7. All costs are based on December 1981 price levels.

For this report, hydropower additions at Knightville Dam are assumed to have an economic life of 50 years. Currently, as prescribed by law, Federal agencies use a 7-5/8 percent interest rate to determine economic feasibility. Construction time for the alternatives under consideration would be about 18 months; therefore, no interest during construction is included. Based on these assumptions, annual costs are shown in Table 8.

TABLE 7

FIRST COSTS FOR ALTERNATIVE PLANS

Item	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Drainage and Erosion Controls	10,000	10,000	10,000	10,000
Access Road	86,000	86,000	86,000	86,000
Reservoir Clearing	200,000	200,000	200,000	-
Parking and Misc. Site Features	20,000	20,000	20,000	20,000
Environmental Controls During Constr.	15,000	15,000	15,000	15.000
Penstock	627,000	627,000	1,696,000	650,000
Bifurcations	42,000	42,000	29,000	42,000
Gates and Valves	587,000	587,000	139,000	576,000
Powerhouse (Civil)	146,000	146,000	219,000	319,000
Turbine and Generator	1,288,000	1,288,000	1,288,000	1,106,000
Misc. Powerplant Equipment	98,000	98,000	98,000	75,000
Electrical Equipment	428,000	428,000	428,000	325,000
Tailrace	51,000	51,000	51,000	51,000
Switchyard	140,000	140,000	140,000	99,000
Transmission Line	57,000	57,000	57,000	51,000
Dam Modification	4,054,000	-	-	-
Spillway Modification	-	3,990,000	3,990,000	-
Control of Water	80,000	80,000	43,000	70,000
Real Estate	70,000	70,000	70,000	-
Contingencies (+20%)	1,571,000	1,535,000	1,691,000	705,000
Total Direct Cost	9,570,000	9,470,000	10,270,000	4,200,000
Engineering and Construction Supervision	1,400,000	1,400,000	1,500,000	600,000
Total Capital Cost	11,000,000	10,900,000	11,800,000	4,800,000

TABLE 8

ANNUAL COSTS FOR ALTERNATIVE PLANS

Item	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Interest and Amortization	858,000	850,400	920,800	375,500
Operation and Maintenance	70,000	70,000	70,000	64,000
Major Replacements	9,500	9,500	9,500	4,200
Total Annual Cost	937,500	929,900	1,000,300	443,700
Energy Production Cost (Mills/Kwh)	99	99	106	94

IV. EVALUATION OF PLANS

Economic Evaluation

This section evaluates the economic benefits which will could accrue from hydropower additions at Knightville Dam.

The conceptual basis for evaluating the benefit from energy produced by hydropower plants is society's willingness to pay for these outputs. Two basic techniques are available for measuring hydropower benefits. The first technique uses estimates of marginal cost to represent the actual or simulated market price of electricity. The second method uses the resource cost of the most likely thermal alternative sources of power to be implemented in the absence of the hydroelectric powerplant. The Federal Energy Regulatory Commission (FERC) estimates the costs and resulting power values under each of the aforementioned methods.

Since this study is in the reconnaissance stage and the installed capacity of each alternative is relatively small, FERC was not asked to compute power values. Due to the variability of costs for energy production and the preliminary nature of this report, an array of benefits was developed based on a range of power values from 70 to 120 mills per Kwh. This range is considered appropriate for this analysis with 100 mills/Kwh considered an approximation of present day value. All benefits are derived by multiplying the annual energy output for each alternative by the unit energy value. FERC will be contacted during the next stage of this study to supply power values. Also, the Office of Power Marketing of the Department of Energy will be contacted and asked to perform a marketing study for the power to be produced at Knightville Dam.

In December of 1979, the Water Resources Council, which formulates procedures used by Federal agencies to evaluate water resources projects, indicated that real escalation in fuel costs should be considered when evaluating hydropower projects. Analysis which takes into account real fuel cost escalation is referred to as relative price shift or inflation free life cycle cost analyses. FERC incorporates this real fuel escalation concept when computing energy values under life cycle analysis. Since the Knightville Project will serve primarily as an oil displacer in oil dependent New England, a simplified fuel escalation analysis is presented. FERC will perform a formal analysis in the next study stage.

TABLE 9

KNIGHTVILLE DAM
ANNUAL HYDROPOWER BENEFITS

	Alt. #1	Alt. #2	Alt.#3	Alt. #4
Head	70 ft.	70 ft.	70 ft.	35 ft.
Installed Capacity	3 MW	3 MW	3 MW	1.5 MW
Annual Energy (Kwh)	9,437,000	9,437,000	9,437,000	4,718,500
Annual Cost	$937,500	$929,900	$1,003,300	$443,700
Energy Production Cost in mills/Kwh	99	99	106	94
Annual Benefits				
@ 70 mills/Kwh	$ 660,600	$ 660,600	$ 660,600	$ 330,300
@ 80 mills/Kwh	755,000	755,000	755,000	377,500
@ 90 mills/Kwh	849,300	849,300	849,300	424,700
@ 100 mills/Kwh	943,700	943,700	943,700	471,800
@ 110 mills/Kwh	1,038,100	1,038,100	1,038,100	519,000
@ 120 mills/Kwh	1,132,400	1,132,400	1,132,400	566,200
Benefit/Cost Ratio				
@ 70 mills/Kwh	.70 to 1	.71 to 1	.66 to 1	.74 to 1
@ 80 mills/Kwh	.81 to 1	.81 to 1	.75 to 1	.85 to 1
@ 90 mills/Kwh	.91 to 1	.91 to 1	.85 to 1	.96 to 1
@ 100 mills/Kwh	1 to 1	1.01 to 1	.94 to 1	1.06 to 1
@ 110 mills/Kwh	1.11 to 1	1.12 to 1	1.03 to 1	1.17 to 1
@ 120 mills/Kwh	1.21 to 1	1.22 to 1	1.13 to 1	1.28 to 1

The following analysis is simplistic since power values were not formally computed; however, the only intention is to emphasize the increasing cost of fuel to be displaced by hydropower generation. The following compounded annual real price escalation rates were computed using 1980 base prices from October 7, 1980, Federal Register, Table C-1 and forecast prices from November 1980 DOE/EIA Service Report SR/IA 180-16, medium price path, average prices, industrial fuels. The rates are for residual fuel in Region One (New England).

Forecast Period	Real Energy Prices Escalation Rate (% Change Compound Annually)
1980-1985	8.3%
1985-1990	2.1%
1990-2010	3.6%

It was ascertained from various sources that roughly 80 percent of the cost of energy production for a thermal plant is fuel. For purposes of analysis, 80 percent of each power value in the range of 70 mills to 120 mills was increased by the appropriate annual percentage to 2010. After escalating the fuel portion, the nonfuel portion (20 percent) was added back in. The value at 2010 was assumed to exist until the 50th year of project life. Escalated energy values for each year of project life were then discounted and annualized over the 50 year project life resulting in a levelized energy value applicable annually. The following table displays energy value.

TABLE 10

ESCALATION OF BASE ENERGY VALUES

Base Value (mills)	70	80	90	100	110	120
Escalated @ 1985	97	111	125	139	153	167
Escalated @ 1990	106	121	136	151	166	181
Escalated @ 2010	193	220	248	275	303	330
Levelized Energy Value	118	135	152	169	185	202

The ultimate effect of escalating the fuel component of the energy values is to increase the benefit to the hydropower project thereby enhancing economic efficiency versus the thermal alternative. The table below displays total benefits with the escalted energy values for the four alternatives.

TABLE 11

ANNUAL BENEFITS USING ESCALATED ENERGY VALUES

	Alt. #1	Alt. #2	Alt. #3	Alt. #4
Annual Benefits				
@ 118 mills/Kwh	$1,113,600	$1,113,600	$1,113,600	$556,800
@ 135 mills/Kwh	1,274,000	1,274,000	1,274,000	647,000
@ 152 mills/Kwh	1,434,400	1,434,400	1,434,400	717,200
@ 169 mills/Kwh	1,594,900	1,594,900	1,594,900	797,400
@ 185 mills/Kwh	1,745,800	1,745,800	1,745,800	872,900
@ 202 mills/Kwh	1,906,300	1,906,300	1,906,300	953,100

To demonstrate the sensitivity of economic justification to the energy value, the table below displays benefit/cost ratios with and without fuel escalation.

TABLE 12

KNIGHTVILLE DAM ECONOMIC ANALYSIS

	Alt. #1	Alt. #2	Alt. #3	Alt. #4
Benefit/Cost Ratio				
@ 70 mills (base)	.70 to 1	.71 to 1	.66 to 1	.74 to 1
@ 118 mills (escal.)	1.19 to 1	1.2 to 1	1.11 to 1	1.25 to 1
@ 80 mills (base)	.81 to 1	.81 to 1	.75 to 1	.85 to 1
@ 135 mills (escal.)	1.36 to 1	1.37 to 1	1.27 to 1	1.44 to 1
@ 90 mills (base)	.91 to 1	.91 to 1	.85 to 1	.96 to 1
@ 152 mills (escal.)	1.53 to 1	1.54 to 1	1.43 to 1	1.62 to 1
@ 100 mills (base)	1 to 1	1.01 to 1	.94 to 1	1.06 to 1
@ 169 mills (escal.)	1.7 to 1	1.72 to 1	1.59 to 1	1.8 to 1
@ 110 mills (base)	1.11 to 1	1.12 to 1	1.03 to 1	1.17 to 1
@ 185 mills (escal.)	1.86 to 1	1.88 to 1	1.74 to 1	1.97 to 1
@ 120 mills (base)	1.21 to 1	1.22 to 1	1.13 to 1	1.28 to 1
@ 202 mills (escal.)	2 to 1	2.05 to 1	1.9 to 1	2.15 to 1

Using the benefit/cost ratio as the criteria for economic justification, generally the four alternatives exceed unity only at energy values over the 100 mill level. As previously mentioned, FERC was not asked to compute power values for this reconnaissance study. However, power values were computed in March 1982 by FERC for a 3.5 MW addition to an existing Corps dam in Connecticut currently under study by this office. For capacity factors under 40 percent, the "at market" energy value based on displaced energy is 105 mills per Kwh.

Social, Cultural and Recreational Considerations

Social Considerations

The addition of hydropower to Knightville Dam is not expected to have significant impacts on the area's socioeconomic resources. Disruption of area activities is expected to be minimal during construction because of the relatively isolated location of the dam. A construction period of 18 months would be required and would provide some temporary employment opportunities. Over the long term, an alteration of recreational opportunities would result as described in the recreational resources section.

Historical and Archaeological Resources

Creation of a permanent pool at 515 feet NGVD would result in continuous inundation of two bridge sites, two cemetery sites, and two farmyard sites consisting of the foundations of dwellings and related outbuildings. All but one farmyard site and one bridge predated 1873.

Creation of permanent pool at 550 feet NGVD would additionally inundate another bridge, a school site and nine farmyard sites. All but the bridge were built prior to 1873.

The three sets of bridge remains consist of either modern concrete features or 19th century stone abutments. These sites and the two former cemetery locations have minimal historical significance.

However, nearly all of the farmyard sites represent occupations dating back to at least the 3rd quarter of the 19th century, and in most cases, probably much earlier. Their present condition may be described as fair. Though some of the foundations may have been partially disturbed during the demolition of structures, subsurface features such as wells and privy pits should be intact. As project planning continues, more detailed study of these sites will be needed to determine the potential historic and archaeological importance of each. Unrecorded historic sites may also be present, and further studies should both locate and identify impacts upon them.

The recorded prehistoric site at Indian Hollow would be above any proposed power pool elevations, but potential sites in similar locations below 515 feet and 550 feet NGVD could be destroyed by clearing prior to inundation or alteration to their environment due to the inundation, itself. Therefore, a cultural resource reconnaissance of this area would be necessary during the next stage of project planning.

In summation, a cultural resource reconnaissance of the proposed pool area below 550 feet NGVD would be necessary during the next stage of project planning. This should include identification of any currently unrecorded prehistoric or historic sites, better delineation of location and condition of recorded historic period sites within the impact area, and assessment of potential project impacts upon such sites.

Recreational Resources

The loss of the inundated shrub bottomland by the 35-foot pool would reduce the number of hunter visitor days that could be expected. Stream fishing in that portion of the river to be inundated would also be lost, but would be replaced by a new lake fishery. The quality of this lake fishery may be questionable due to the relatively shallow depths and probable warm water temperatures. Additional recreational activities, such as boating or swimming, could be provided if desired. Boating could be accommodated by the provision of a boat launching ramp at either one of two access points where existing project roads lead to the pool.

With a 70-foot pool, nearly all of the present pheasant hunting would be eliminated along with about half of the existing stream fishery. But with deep, cold water, it is possible that a lake fishery rivaling that at Littleville Lake could be established. If this were the case, potential use by fishermen could approach the 30,000 fishermen days presently experienced at Littleville. Recreational boating would also be permitted since the lake would not be a water supply. In addition, other recreational opportunities could be provided, if desired, and include a swimming beach, picnic area and related day use facilities. Access to the lake could be provided at two locations over existing project roads. Overall, significant recreational potential exists with establishment of a 70-foot pool, with the greatest loss being the elimination of the present pheasant hunting. Less recreational potential exists with establishment of a 35-foot pool, although loss of existing recreation (stream fishing and hunting) would be less. Whitewater canoeing potential downstream of Knightville Dam could be enhanced with either pool alternative when releases are made which increase the normal stream flow to acceptable levels. It is not expected that other recreational activities at Knightville would be affected by establishment of either power pool.

Environmental Considerations

Physical Setting

The creation of a permanent reservoir would reduce the streambed area available for natural erosion during high flow conditions. The amount of sediments carried downstream would be trapped within the impoundment. The reservoir would permanently inundate the stream banks along the present stream courses, which periodically slough debris into the streams. Some of the existing terraces at the reservoir level may become unstable because of wave action at the power pool elevation. The reservoir would create a dendritic lake not unlike those formed during the last glacial recession.

The proposed reservoir would leave any sand and gravel deposits in the valley unavailable for future use. Coarser deposits would be available only from areas higher up on the valley walls. The proposed project would add to the deposition of fine-grain materials such as sand, silt and clay within the impoundment area.

The creation of a permanent power pool in the project area would have no significant impact on the macro-climate of the region. The air temperature surrounding the lake may slightly change due to the influence of a nearby body of water, but the change would be insignificant. Fog may occur more often in the project area because of differences between the water and air temperatures.

Aquatic Ecosystems

The establishment of a permanent power pool at the Knightville facility would change a modified flowing water habitat into that of a standing water habitat. Impacts to the present aquatic ecosystem by the 35 and 70-foot pool are addressed below.

The 35-Foot Power Pool

Establishment of the 35-foot pool will create a 90-acre lake, which would inundate about 3.1 miles of the East Branch of the Westfield River upstream of the dam site. Approximately 0.3 miles of the lower section of the Little River and smaller portions of the four remaining tributaries would also be inundated. The 90-acre power pool with a target elevation of 515 feet NGVD would not vary on a daily basis due to hydropower operation as the project would be operated strictly as run-of-river. However, pool fluctuations would still be experienced during flood control operations.

The relatively shallow impoundment, if density stratified, would likely exhibit a relatively small hypolimnion in the late summer months. Verification of any stratification and the temperature gradient are pending further study at a later stage in planning.

Initial flooding would release nutrients from the land cover and soils which would temporarily increase the primary and secondary productivity of the entire reservoir. Surges in phytoplankton productivity would be followed by zooplankton increases. A shift in species composition from lotic and lentic forms would also occur. The increased biological oxygen demand in the hypolimnion would decrease the dissolved oxygen concentration and may limit deep benthic fauna to forms which are capable of tolerating low oxygen levels such as the oligochate Tubifex sp. and the midge larvae of Chironomus sp. As the lake stabilizes, productivity would return to lower levels and remain at an established equilibrium. Once nutrient stabilization occurs, nearshore benthos, an important food source for some fish, would also decrease as a result of continued pool fluctuations, freezing and erosion.

Fish populations would generally survive the initial flooding. However, as the general productivity and temperatures increase, the reservoir would not be suitable as a habitat for coldwater species. Warmwater species such as white sucker, and sunfish may actually benefit and increase their productivity.

In general, insect populations associated with a stream habitat would shift to populations more associated with a standing water habitat.

The 70 ft. Power Pool

Establishment of a 70-foot pool will create a 370-acre lake which would inundate about 3.9 miles of the East Branch of the Westfield River. Approximately 0.6 miles of the Little River and smaller sections of the five remaining streams would also be inundated. As with the 35-foot pool, the 70-foot pool will not experience any fluctuations due to hydropower operations.

General productivity of the lake would increase after initial flooding and decrease once stabilization took place. Impacts to the various trophic levels would probably occur as described for the 35-foot pool. The time required for stabilization would be longer than that of the 35-foot pool. Further study would be needed to estimate such a time.

Once stabilization does occur, the resulting limnology and aquatic life may be similar to that described in Littleville Lake Preliminary Feasibility Study for Hydropower Development.[2] Although the size and depths of both impoundments would be similar, further study would be needed to verify similarities in general limnology. The lake is deep enough to have the potential to provide a trout fishery similar to that of Littleville.

Downstream Impacts

Use of the 16-foot diameter tunnel or the 12-foot penstock for power generation will draw water from the bottom of the reservoir at 480 feet NGVD. If late summer stratification develops and is similar to that of Littleville, anoxic water may be released downstream through the outlet works. Released water from the 35-foot pool may be less anoxic than that of the 70-foot pool but will be at higher temperatures. In either case, coldwater species immediately downstream may be stressed or killed if exposed for a sufficient length of time. Anoxic water would eventually reoxygenate as it travels downstream so that this effect would be decreased further away from the outlet works.

Construction of the powerhouse in the downstream area would cause disruption of a 200 feet by 200 feet section of the streambank area and may cause minor siltation in the immediate area. Some material may be carried downstream but would eventually settle in areas of low current velocity. It is not expected that this would unduly stress downstream aquatic organisms.

Downstream flows from the outlet works would not differ from the variations associated with present flood control operations. The greatest variations would occur during flood and drought periods. A minimum flow would be maintained for downstream water quality purposes. Hydropower operations would be shut down during low flow periods.

Water Quality

The water quality changes caused by hydropower development at Knightville Dam will depend on the type of impoundment created at the project, whether reservoir lands are cleared of vegetation, and how it is operated. The proposed 70-foot deep impoundment would probably experience temperature-induced density stratification with the consequent possibilities of water quality degradation such as low dissolved oxygen levels in the hypolimnion and nutrient enrichment. Temperature changes in the river

[2] U.S. Army Corps of Engineers, New England Division, 1980. Littleville Lake Hydropower Development, Preliminary Feasibility Study.

downstream from the dam would be expected. The deep impoundment might also trap sediment and allow bacterial die-off, thus improving the downstream water quality in these respects.

The principal effect of the smaller 35-foot deep impoundment would be to warm the water and increase the violations of temperature criteria for a coldwater fishery. Some settling out of the sediment load during storms would also be expected. This shallower pool may become stratified and experience similar problems as outlined above.

Future studies will be directed towards the determination of the type of reservoir site preparation, the need for selective withdrawal capability at the project, the subsequent design of a multi-level outlet structure and the detailed analyses for prediction of water quality conditions in the reservoir and downstream.

Terrestrial Ecosystem

Vegetation

Establishment of the 35-foot power pool would permanently inundate about 90 acres of shrub bottomland up to 515 feet, NGVD. Much of this vegetation, comprised mainly of grasses, willows, adlers, dogwoods and other flood tolerant species, would either die from total inundation or be removed prior to filling. Because the treeline (elevation 540 feet) is well above the 515 feet target elevation, no trees would be inundated under this alternative. Wetland areas at the bottom of the present reservoir and at the mouth of Little River would also be inundated. This includes the cover and food plantings of the MDFW for the pheasant stocking program.

More protected areas should allow establishment of emergent littoral plants such as bulrush (*Scripus* sp.), cattails (*Typha* sp.), smartweeds (*Polygonum* sp.) and sedge (*Carex*).

Implementation of the 70-foot pool would inundate about 370 acres of the vegetation upstream of the dam to 550 feet NGVD. The reservoir would inundate all of the shrub bottomland and the lower 10 feet of the treeline (elevation 540) up to the 550 target elevation. The precise elevation to be cleared will be determined at a later stage in planning. Trees in the lower portion of the new treeline may not survive inundation during flood storages. Trees at these elevations would not be exposed to inundation as frequently or for as long as trees at lower elevations. Some trees are more flood tolerant than others based on anatomical and physiological adaptions to compensate for soil oxygen depletion during inundation. McKim *et al.* (1975)[2] found that hemlock, sugar maple, birch and beech are

[2]McKim, H.L., L.W. Gatto and C.J. Merry. 1975. Inundation Damage to Vegetation at Selected New England Water Control Reservoirs, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

relatively intolerant to flooding during the growing season whereas red and silver maple, white ash, and red oak were relatively tolerant to various degress. Trees of the former group in the lower portion of the treeline may not survive. The species composition in this area may shift over the long term to more members of the latter group.

In addition to the wetland at the bottom of the reservoir, more area of the Little River wetland would be inundated under the 70-foot pool.

Wildlife

The impacts on wildlife are generally proportional to the amount of disturbed habitat that species are associated with. Thus, impacts associated with the 70-foot pool are higher in magnitude that those of the 35-foot pool. Although the identification of specific impacts would require further study, the following general statements can be made.

Wildlife associated with the inundated habitat would perish or move into adjacent lands when the lake is filled. This displacement would put pressure on surrounding populations whose habitat may be already operating under maximum carrying capacity. Local increases in these surrounding populations would increase browsing in these areas and may temporarily reduce productivity.

A significant loss is the 296-acre area which services as habitat for MDFW pheasant management program. The 35-foot pool would inundate over a third of this area, whereas the 70-foot pool would inundate all of it.

Creation of the lake may increase waterfowl use of the area. The lack of daily pool fluctuations would allow establishment of littoral vegetation which could serve as a suitable food and habitat for certain species.

Rare, Threatened and Endangered Species

Since there are no currently listed Federal threatened or endangered species in the project area, no impacts are anticipated from implementation of the proposed project. Any state rare or local species residing in the project area would receive special consideration according to Massachusetts State Law.

Reservoir Regulation

If hydropower faciliites are eventually built on the site, the primary purpose of the project will remain flood control, and all flood control activities will override the requirements of hydropower generation. This control would be retained by the Division Engineer through the Corps' Reservoir Control Center.

V. CONCLUSIONS

Based on the preliminary findings presented in this reconnaissance report, it appears that the addition of hydroelectric facilities at the Corps' Knightville Dam is feasible, based on life cycle analysis over a 50-year project life. It has been determined that if a 35-foot, 90-acre, permanent pool were created at the project and two 750 kilowatt Kaplan type turbines were installed, an average of 4,718 megawatt-hours of energy would be produced annually at a cost of about 94 mills per kilowatt-hour.

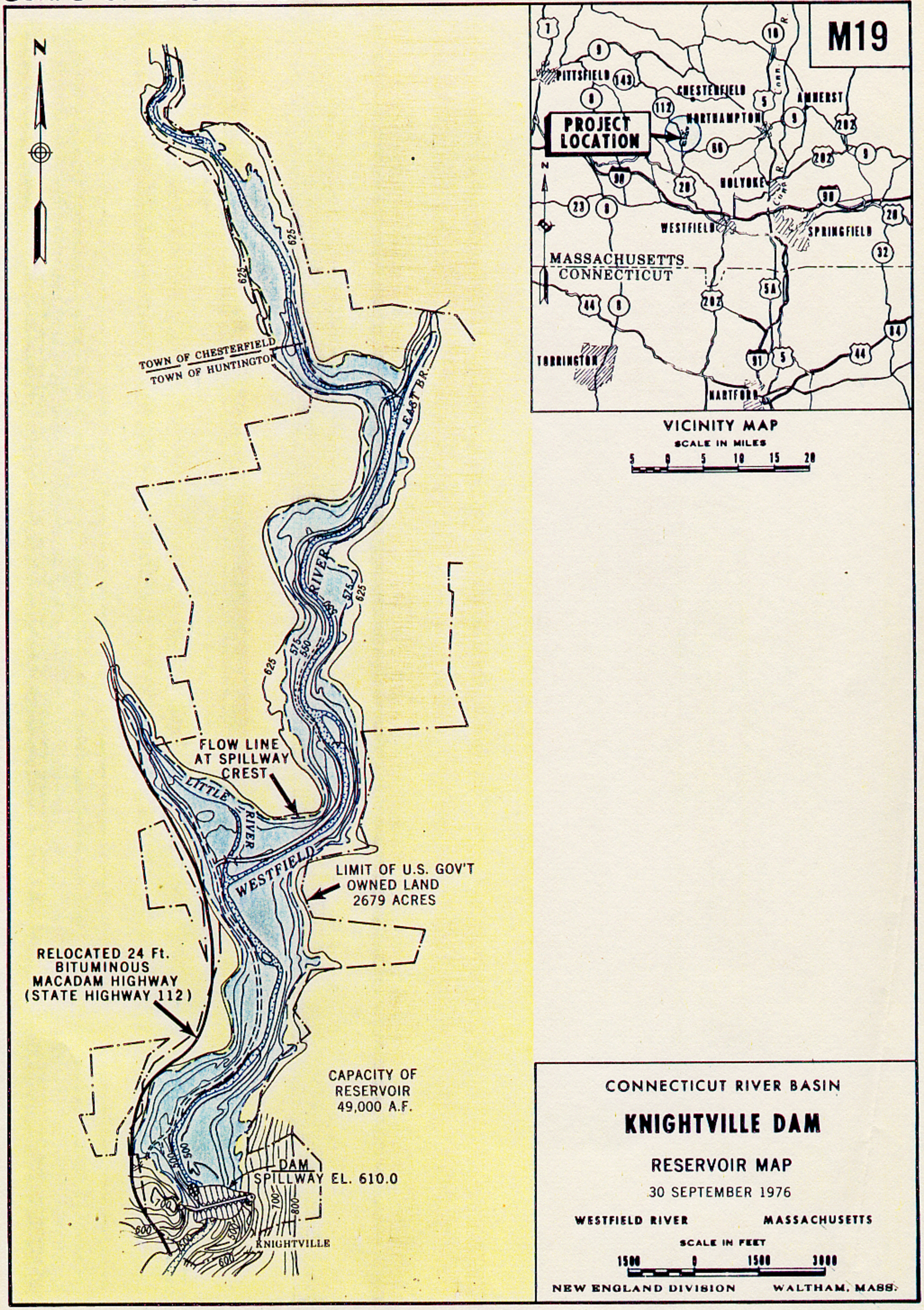
As this planning effort continues, detailed studies will be performed to verify these findings, evaluate other possible alternatives and further assess environmental, social, recreational and cultural impacts.

ACKNOWLEDGEMENT

This study was conducted by the New England Division, Army Corps of Engineers, under the supervison of Mr. Joseph L. Ignazio, Chief, Planning Division; Mr. William F. McCarthy, Chief, Basin Management Branch; and Mr. Harmon H. Guptill, Chief, Hydroelectric Energy Studies Section. Investigations were performed by an interdisciplinary project team. Persons primarily responsible for the contents of this report are: Anthony Firicano, Project Manager; Eugene Brickman and Paul L'Heureux, geotechnical aspects; Mary Donovan and James O'Leary, design; David Tomey, environmental aspects; Donald Buelow, water quality; Farrell McMillan, hydrologic and hydraulic aspects; John Wilson, cultural aspects; Douglas Cleveland, recreation; Richard Ring, economics; Diana Halas, socioeconomic aspects; and Joseph Finegan, reservoir regulation.

Preparation and distribution of this report would not have been possible without the cooperation of the Division's technical, clerical and administrative staffs. Special thanks are extended to the entire staff of the Reprographics Branch and Word Processing Center.

PLATES



CONNECTICUT RIVER BASIN

KNIGHTVILLE DAM

RESERVOIR MAP

30 SEPTEMBER 1976

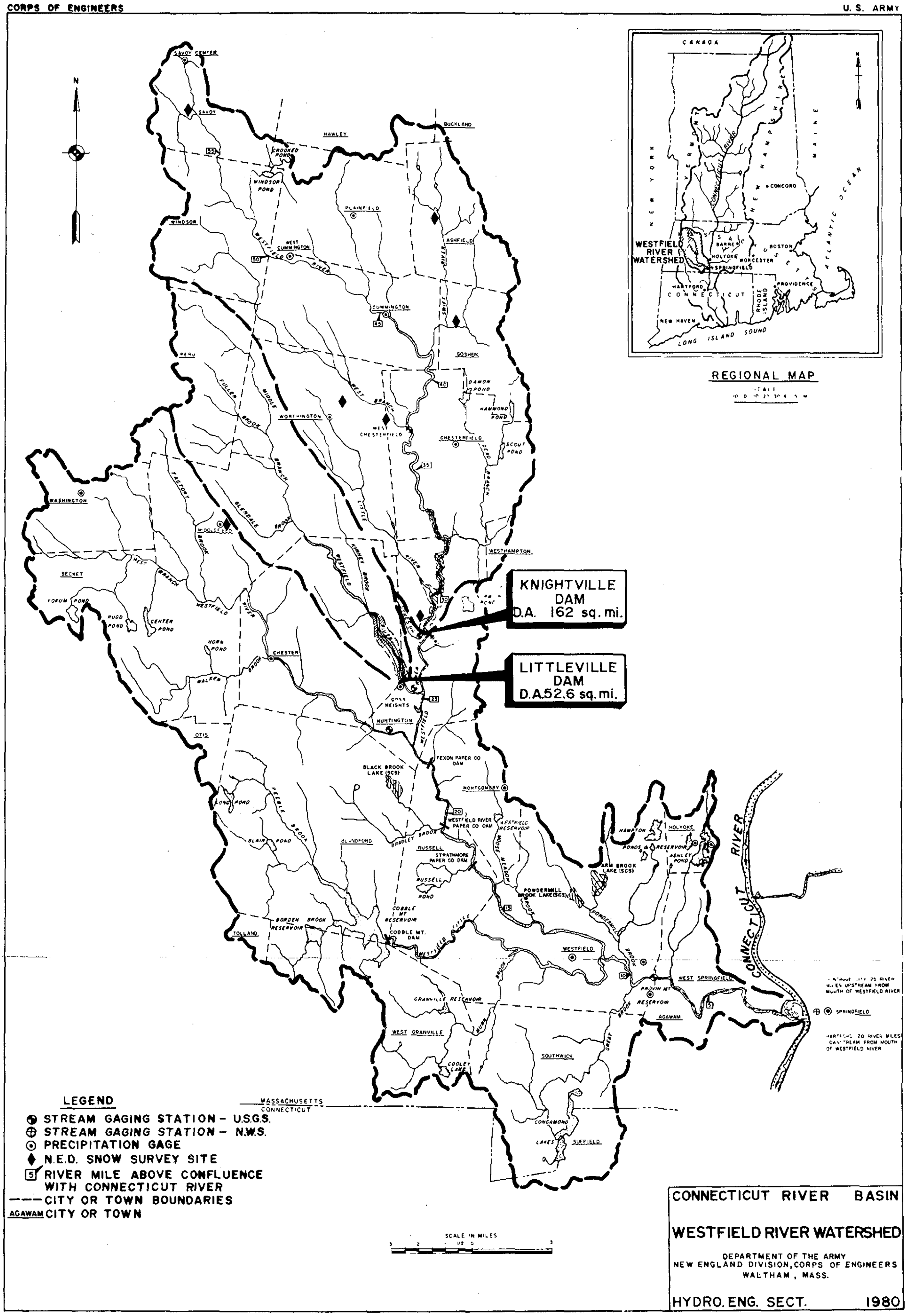
WESTFIELD RIVER MASSACHUSETTS

SCALE IN FEET

1500 0 1500 3000

NEW ENGLAND DIVISION WALTHAM, MASS.

CORPS OF ENGINEERS U. S. ARMY



CONNECTICUT RIVER BASIN

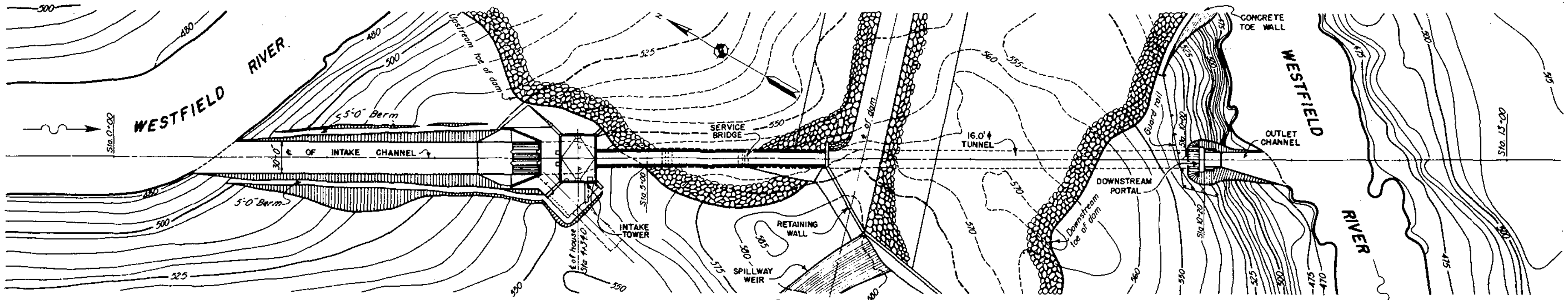
WESTFIELD RIVER WATERSHED

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

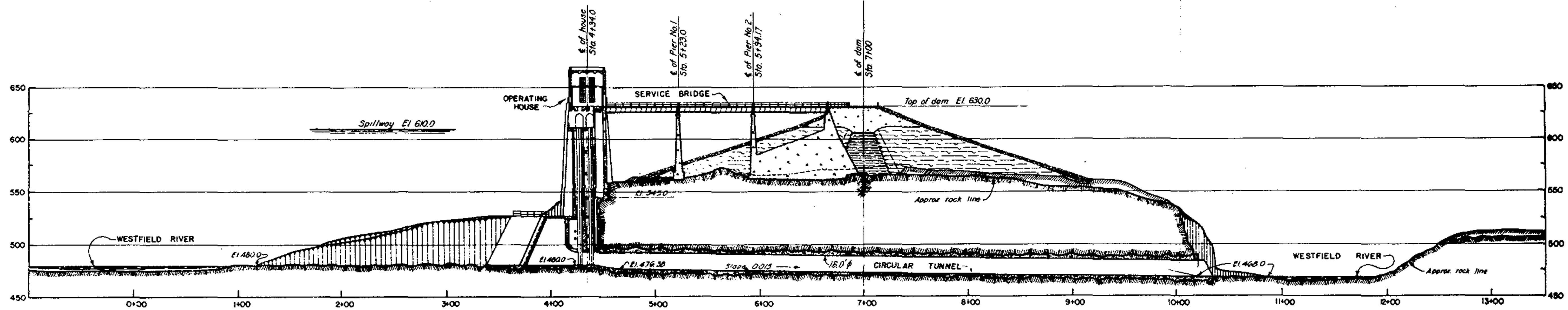
HYDRO. ENG. SECT. 1980

PLATE 2


Flow Line Spillway Crest
€ of tunnel and bridge
Sta. 0+00
Limits of area to be cleared
INTAKE CHANNEL
Brook diversion ditch
Axis of main upstream cofferdam
INTAKE TOWER
SPILLWAY WEIR
Length of crest = 405'
El. 610.0
SERVICE BRIDGE
Sta. 0+00 (Access road)
€ of dam
Top of dam El. 630.0
Power cable
Sta. 0+00
ROTARY
Operator's quarters
RETAINING WALL
TUNNEL
Sta. 10+00
DOWNSTREAM PORTAL
Rock pinnacle
Toe drainage ditch
CONCRETE TOE WALL
Brook diversion ditch
Limits of area to be cleared
Wood road
Limit of work area
RIVER
WESTFIELD
ACCESS ROAD
Sta. 5+00
Sta. 10+00
Sta. 15+00
Sta. 20+00
Limit of work area
Existing State Highway 112 to Huntington 4 mi.
PLAN
SCALE 1" = 100'
100' 0 100' 200'
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
WATER RESOURCES DEVELOPMENT PROJECT
CONNECTICUT RIVER BASIN
KNIGHTVILLE DAM
GENERAL PLAN
WESTFIELD RIVER
MASSACHUSETTS
SUBMITTED:
PROJECT ENGINEER
REVIEWED:
CHIEF
APPROVAL RECOMMENDED:
CHIEF
BRANCH
APPROVED
DATE
CHIEF, ENGINEERING DIVISION
SCALE: AS SHOWN
SPEC. NO. DACW 33
DRAWING NUMBER



PLAN
SCALE 1 IN = 40 FT.

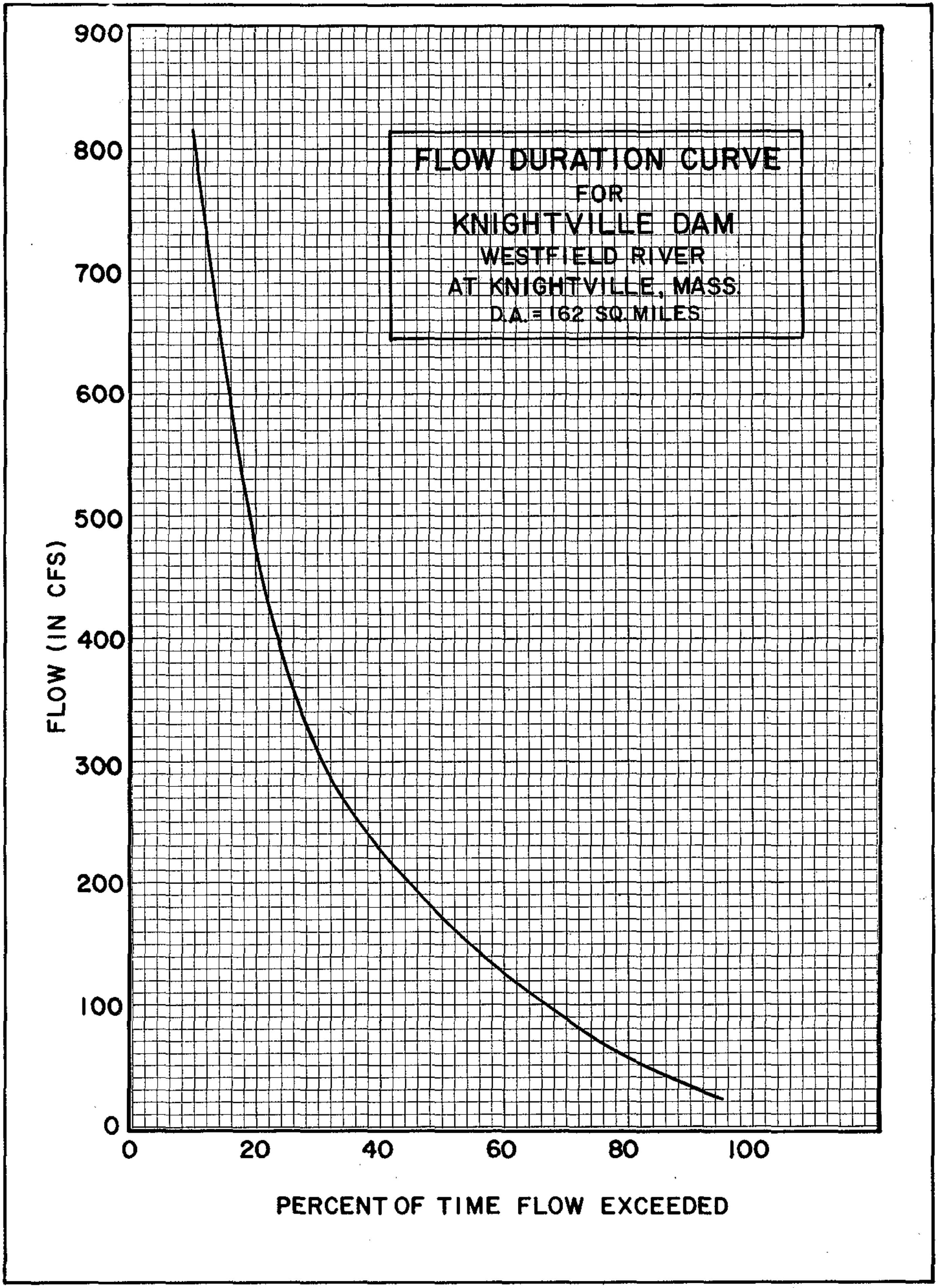


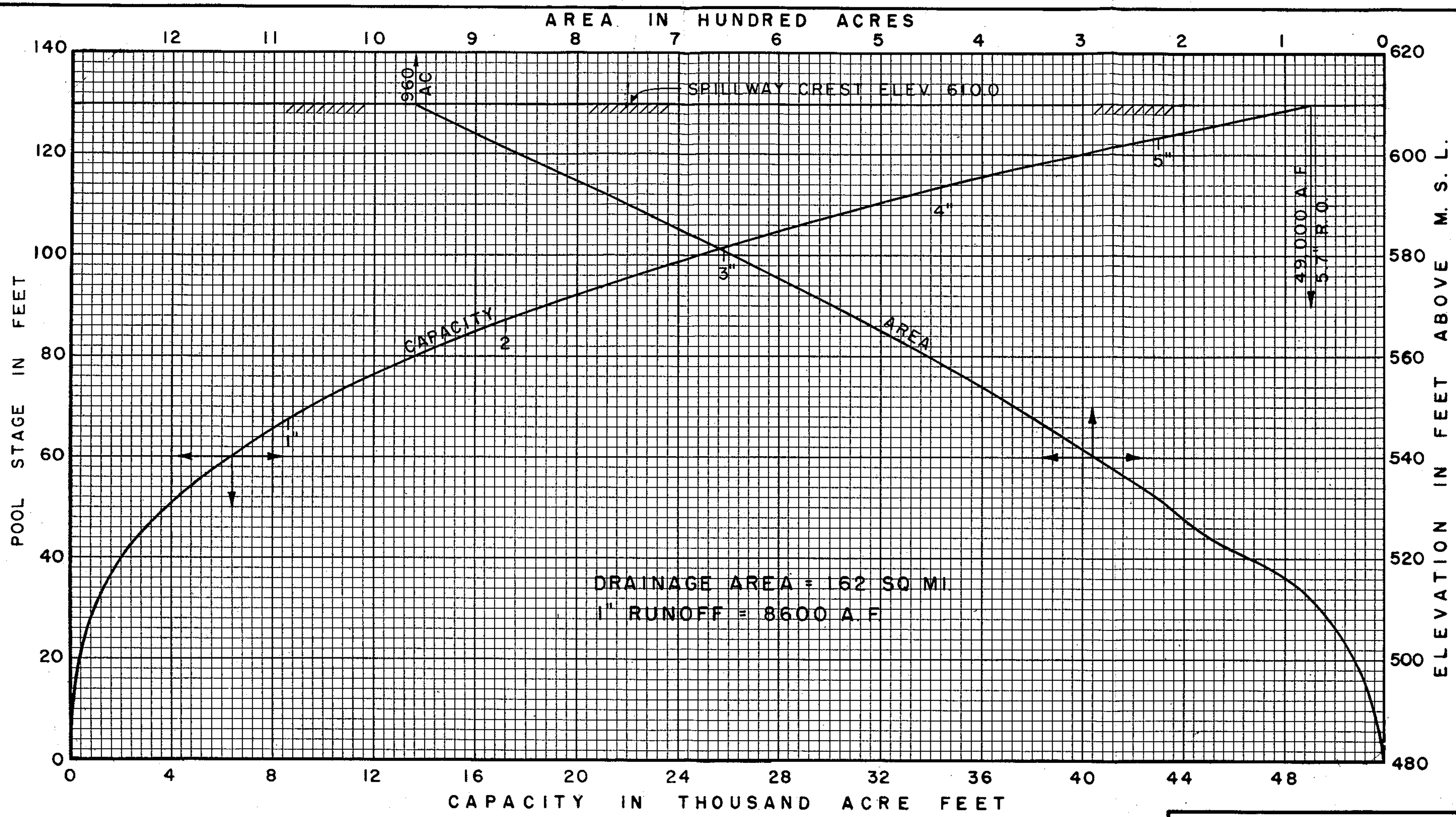
SECTION ON CENTER LINE OF TUNNEL
SCALE 1 IN = 40 FT

SCALE 1" = 40'
40' 0 40' 80'

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	DR. BY	CK. BY	WATER RESOURCES DEVELOPMENT PROJECT
SUBMITTED:			CONNECTICUT RIVER BASIN
CHIEF, SECTION			KNIGHTVILLE DAM
APPROVAL RECOMMENDED:			OUTLET WORKS
CHIEF, TECH. ENG. BRANCH			PLAN AND PROFILE
REVIEWED: PROJECT ENGINEER			WESTFIELD RIVER MASSACHUSETTS
APPROVAL RECOMMENDED:			APPROVED DATE
CHIEF BRANCH			CHIEF, ENGINEERING DIVISION
			SCALE AS SHOWN SPEC. NO. DRAWING NUMBER


FLOW DURATION CURVE
FOR
KNIGHTVILLE DAM
WESTFIELD RIVER
AT KNIGHTVILLE, MASS.
D.A. = 162 SQ. MILES
FLOW (IN CFS)
0
100
200
300
400
500
600
700
800
900
0
20
40
60
80
100
PERCENT OF TIME FLOW EXCEEDED



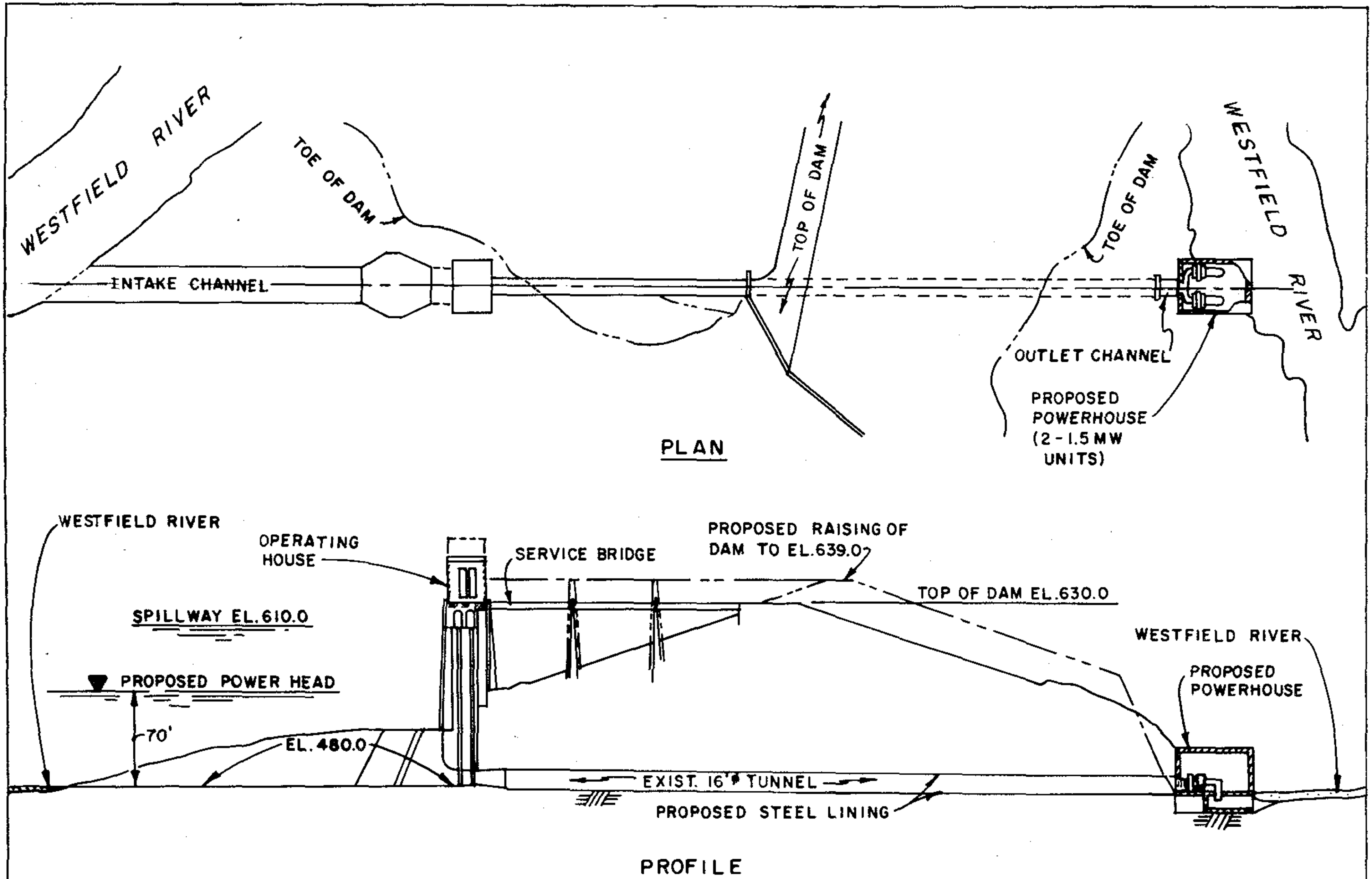
WATER RESOURCES DEVELOPMENT PROJECT

CONNECTICUT RIVER BASIN

KNIGHTVILLE DAM

AREA & CAPACITY CURVES

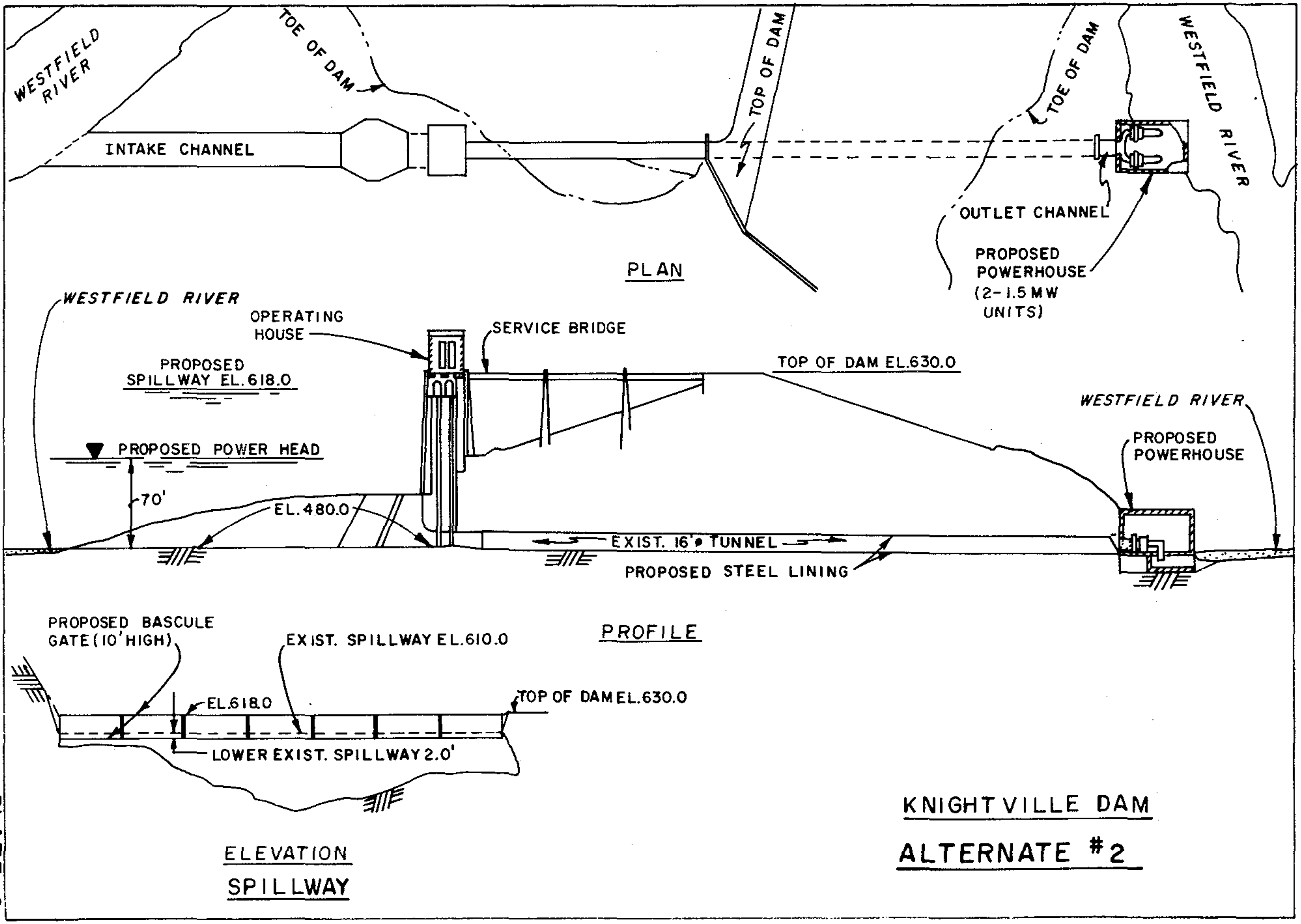
NEW ENGLAND DIVISION, WALTHAM, MASS.
SEPT. 1976



KNIGHTVILLE DAM

ALTERNATE # 1

PLATE 7



KNIGHTVILLE DAM

ALTERNATE #2

PLATE 8

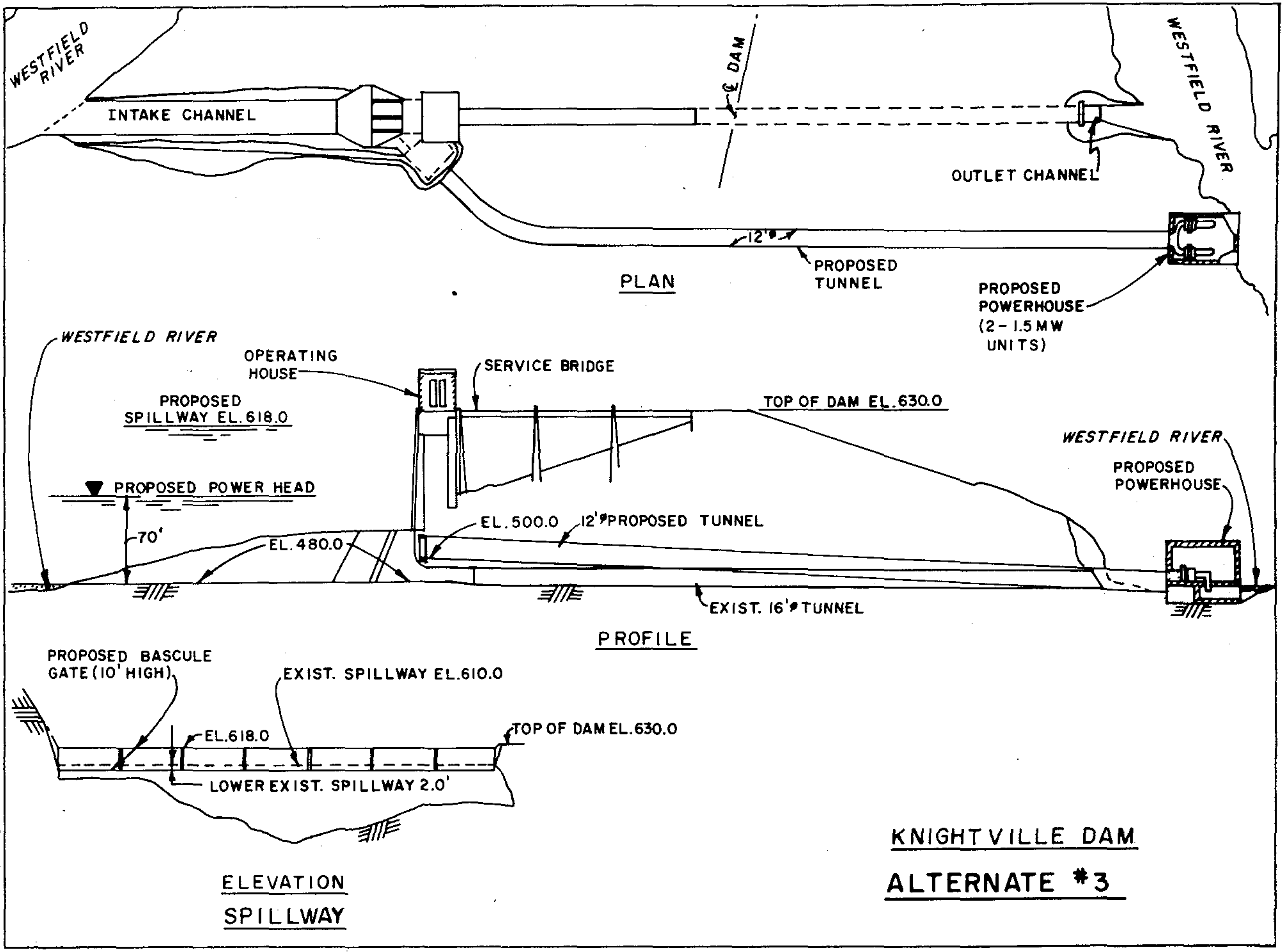
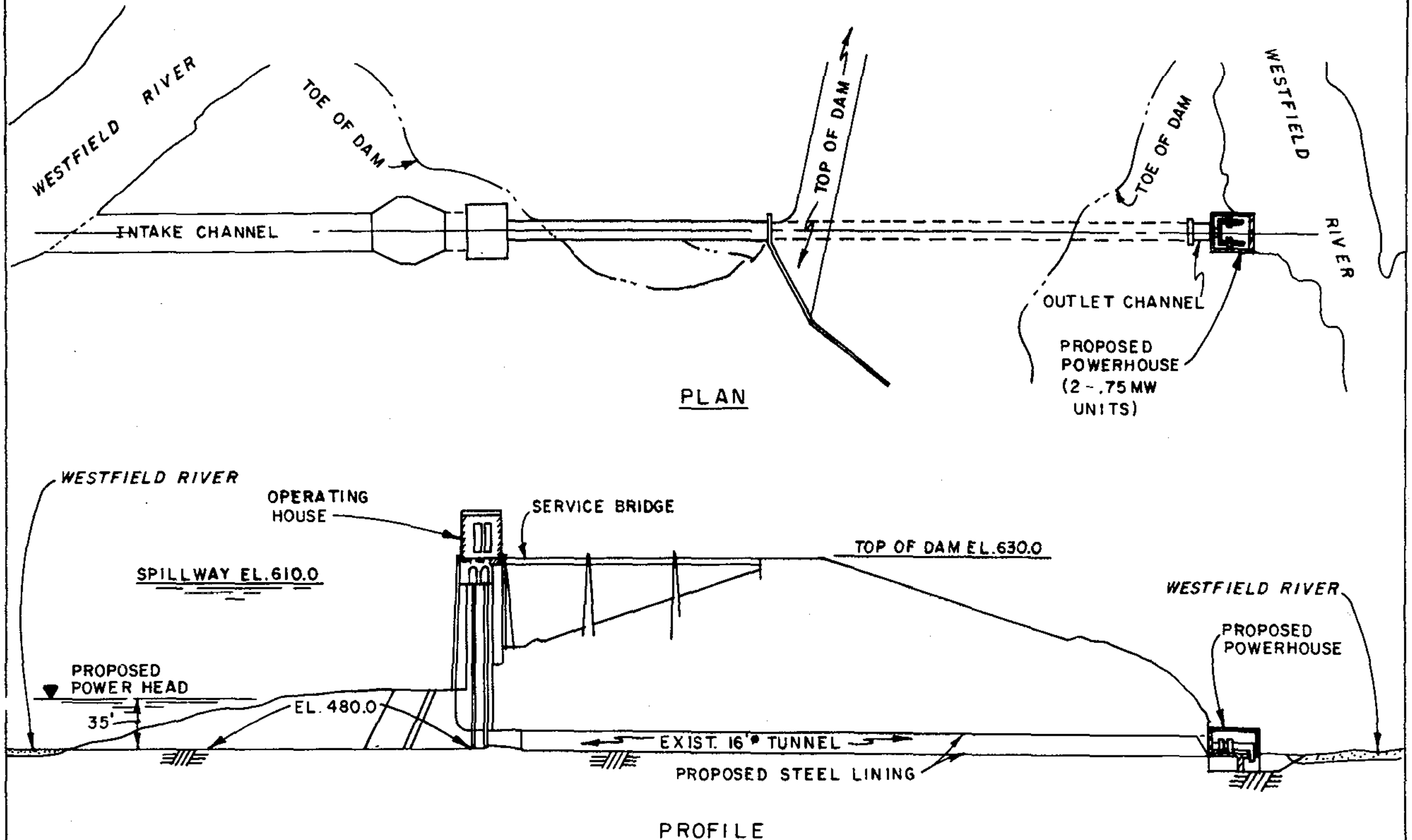

WESTFIELD RIVER
INTAKE CHANNEL
℄ DAM
WESTFIELD RIVER
OUTLET CHANNEL
12'φ
PROPOSED TUNNEL
PLAN
PROPOSED POWERHOUSE (2 - 1.5 MW UNITS)
WESTFIELD RIVER
OPERATING HOUSE
SERVICE BRIDGE
PROPOSED SPILLWAY EL. 618.0
TOP OF DAM EL. 630.0
WESTFIELD RIVER
PROPOSED POWERHOUSE
PROPOSED POWER HEAD
70'
EL. 480.0
EL. 500.0
12'φ PROPOSED TUNNEL
EXIST. 16'φ TUNNEL
PROFILE
PROPOSED BASCULE GATE (10' HIGH)
EXIST. SPILLWAY EL. 610.0
EL. 618.0
TOP OF DAM EL. 630.0
LOWER EXIST. SPILLWAY 2.0'
ELEVATION
SPILLWAY
KNIGHTVILLE DAM
ALTERNATE #3

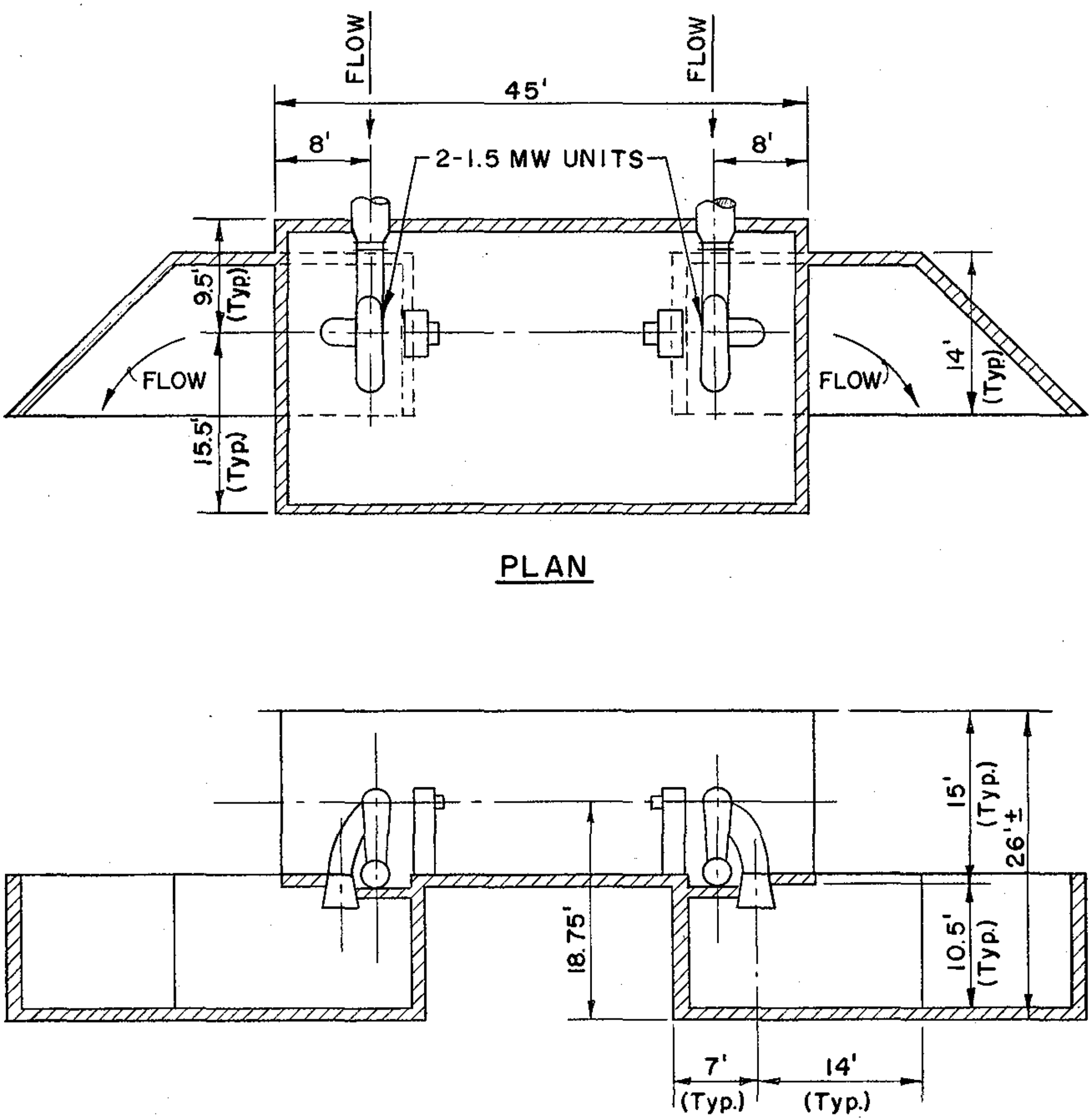
PLATE 9



KNIGHTVILLE DAM

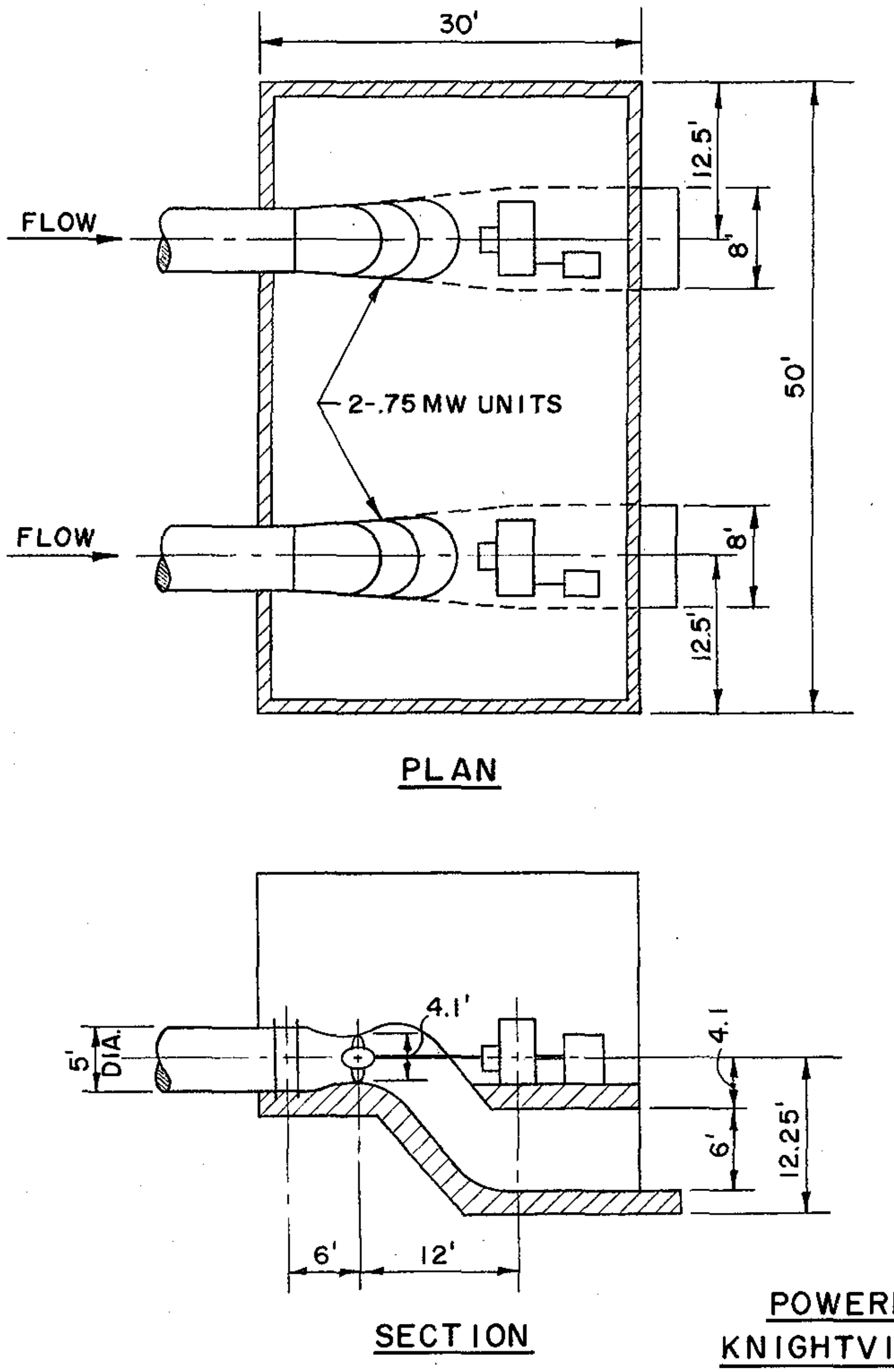
ALTERNATE *4

PLATE 10



POWERHOUSE
KNIGHTVILLE DAM
ALTERNATE #1, 2 & 3 (70' HEAD)

PLATE 11



POWERHOUSE
KNIGHTVILLE DAM
ALTERNATE #4 (35' HEAD)

PLATE 12